ACTA RADIOLOGICA

OFFICIAL ORGAN OF THE RADIOLOGICAL SOCIETIES OF DENMARK, FINLAND, NORWAY AND SWEDEN

EDITOR ERIK LINDGREN

DIAGNOSIS

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CYSTOURETHROGRAPHY AND FEMALE URINARY STRESS INCONTINENCE

by

J Hoffmann and J Ulrich

Female urinary incontinence is generally a result of pathologic changes in and around the organs of micturition, especially in women who have borne children the predominant etiologic factor being trauma The pathogenesis, upon which there is less agreement, is more complicated however

Urinary incontinence in both males and females may be the result of a lesion of the sphincter, either muscular or neuromuscular Fransson & Petersén (1956) and Danielson et coll (1955) electromyographically examined the sphincters of a group of uniparae and multiparae These authors reported that all regardless of whether they suffered from urinary incontinence or not had a muscular defect in the posterior part of the sphincter the part closest to the vagina They believed that a sufficiently extensive rupture of the circular sphincter always results in urinary incontinence Roentgenologically such a rupture is demonstrated as a broad funnelling of the most proximal

From the Department of Roentgenology (Directors E de Fine Licht and Olaf Petersen) and the Department of Gynecology and Obstetrics (Director Valdemar Madsen) Copenhagen County Hospital Gentofte Denmark This paper was presented in an abbreviated form to the III World Congress of Gynecology and Obstetrics Vienna 1961 Submitted for publication 26 February 1964

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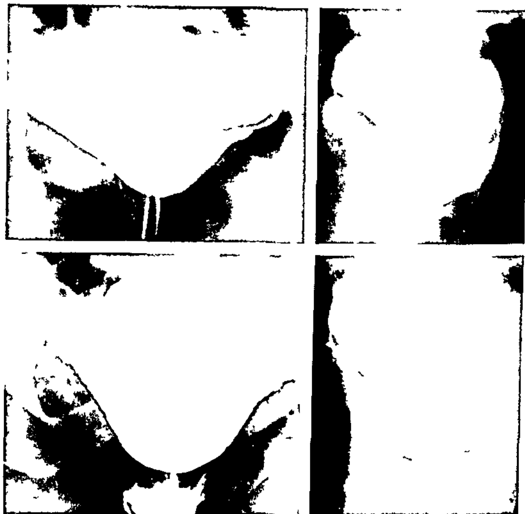


Fig 1 Woman aged [illegible] with genital prolapse and stress incontinence (group A)

part of the urethra KARLSON *(1952) stated that any disorders permitting* urine to seep down into the upper part of urethra will give rise to micturition Other authors maintain that the position of the proximal part of the urethra in relation to the base of the bladder is pathogenetically of greater importance They have primarily been interested in the angle formed between the proximal part of the urethra and the posterior surface of the bladder, the so called posterior urethrovesical angle During stress the pelvic floor is lowered, the posterior surface of the bladder also descending, although disproportionately In this way the posterior urethrovesical angle is increased to 180° or more, and theoretically the possibility of urine seeping out then arises in spite of the influence of the sphincter

THOMSEN (1930, 1932) was the first in Scandinavia to investigate female urinary incontinence roentgenologically He described angulation of the



Fig ? Woman aged 37 with genital prolapse but without stress incontinence (group B)

upper part of the urethra in normal cases an increase of this angle to 180 was found in cases of female urinary incontinence STEVENS & SMITH (1937), using a technique similar to the one employed by THOMSEN but supplemented by insertion of a metal chain into the urethra found no evidence of angulation They considered the main reasons for incontinence to be lesions in and around the urethra

MILLER (1938) and MORRIS & BRUNTON (1933) performed cystography in incontinent women before and after operation It was concluded that the elevation and fixation of the bladder neck is of the greatest importance if the operation is to be a success CRABTREE et coll (1936) used cystourethrography to diagnose lesions of the sphincter and other urethral abnormalities They believed that urinary incontinence in women who had borne children could generally be referred to the sphincter INGELMAN SUNDBERG (1950) stated

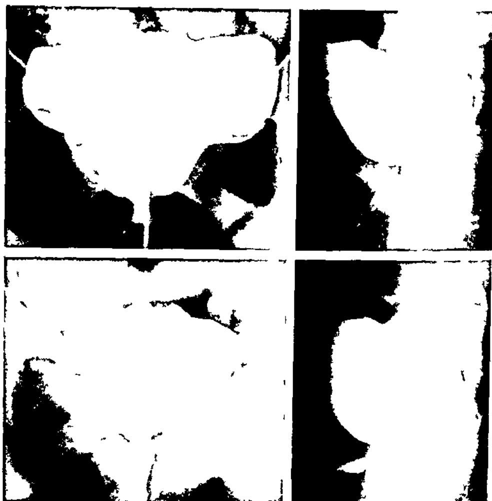


Fig 3 Woman aged 51 without genital prolapse but with stress incontinence (group C)

that fixation of the bladder to the pelvic symphysis may cause incontinence BALL (1950) stressed the importance of fixation of the bladder neck, as he found that a downward displacement of the neck caused funnelling of the upper part of the urethra with consequent incontinence

JEFFCOATE & ROBERTS (1952) described frequent funnelling of the proximal part of the urethra in cases of stress incontinence but considered that the size of the posterior urethrovesical angle to be of greater importance in the diagnosis of stress incontinence This angle was obliterated in 80 % of incontinent women, the obliteration being evident during stress (sneezing, coughing or straining) even in less severe cases of incontinence Obliteration of this angle was present even without straining in more severe cases Obliteration could be observed although only during micturition, in normal cases Depression of the bladder base and funnelling was not considered to be of any great

significance, as the authors had seen patients who became continent solely by reestablishment of the posterior urethrovesical angle even though funnelling persisted

GLEICHAUF (1959) found that the size of the posterior urethrovesical angle was of no importance in the diagnosis of stress incontinence MOLNAR & KAPU (1960) considered funnelling (which they called 'vertical descensus') and depression of the bladder base to be of considerable importance in the diagnosis of stress incontinence whereas they found complete obliteration of the posterior urethrovesical angle in only 30 % of the incontinent patients whom they examined

All the above mentioned examinations were performed with the help of iodine contrast media NORDENSTROM (1952) used a suspension of one part barium sulphate to three parts water as contrast medium for exposures during micturition but like earlier examiners employed a metal chain to outline the urethra during stress This author obtained far better lateral roentgenograms than earlier examiners and demonstrated narrowing of the upper and lower parts of the urethra When this narrowing of the lumen was not seen funnelling and an obliteration of the urethrovesical angle were present He considered that funnelling and an increased angle were very often present in stress incontinence To ensure that the use of barium did not result in the formation of bladder stones a belief that was — and still is in some quarters — widespread NORDENSTROM performed cystoscopy on each patient 24 hours after cystourethrography without finding residues of the contrast medium

NIELSEN (1958) examined 100 incontinent women by the Nordenstrom technique and reported funnelling to be the most common abnormality followed by obliteration of the posterior urethrovesical angle A downward displacement of the internal urethral orifice was also a common finding

These contradictory findings and conclusions from previous cystourethrographic examinations would appear to have been partly due to the methods used The present authors have therefore performed a series of cystourethrographic examinations with a modified technique in female patients suffering from stress incontinence The examination may be performed without any noticeable deformation of the urethra or bladder

Technique The patient having been instructed to empty the bladder, is placed on a fluoroscopy couch and a soft polythene catheter about 3 mm in diameter is introduced into the urethra and bladder A solution made up of equal parts of sterile micro disperse barium sulphate and sterile physiologic saline is injected into the bladder the catheter is then filled with 5 ml undiluted barium sulphate The injection having been made the catheter is

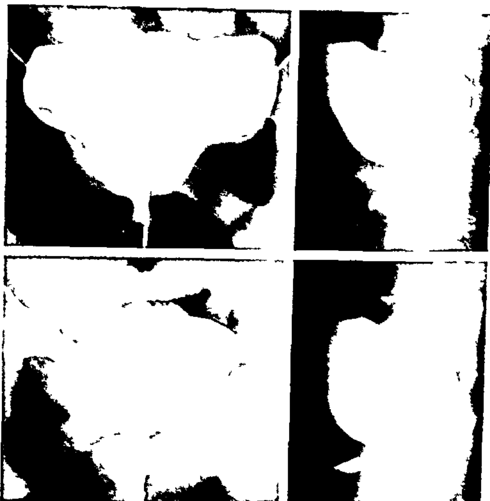


Fig 3 Woman aged 51 without genital prolapse but with stress incontinence (group C)

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Table 1

Data and results of cystourethrographic examinations in 68 patients

	Group A (prolapse and stress incontinence	Group B (prolapse without stress incontinence)	Group C (without prolapse but with stress incontinence)	Group D (without prolapse or stress incontinence)
Number of cases	32	15	7	14
Average age	46.9 (70—31) years	45.4 (67—41) years	48.4 (54—33) years	40.4 (55—28) years
Average number of births	2.3 (6—1)	2.3 (4—1)	2.4 (4—0)	1.6 (4—0)
Average degree of bladder base depression during straining (± 1 mm)	20 mm (12—15)	18 mm (10—15)	15 mm (5—35)	16 mm (10—35)
Number of cases presenting funnelling	9	2	1	1

closed, fixed to the patient's thigh, and the couch raised until the patient is erect

Frontal roentgenograms of the bladder and the urethra, doubly exposed, are now obtained, the patient having been instructed not to move between the two exposures The first exposure is obtained with the patient holding her breath and the second after she has been requested to strain as if to micturate Lateral doubly exposed roentgenograms are thus obtained, if satisfactory, the catheter is removed, and lateral and frontal roentgenograms are obtained during micturition

The lateral exposures are always taken first, as many patients have difficulty in stopping micturating while they are turned for the next exposure, in addition to which the lateral projections give clearer views of the shape and location of the base of the bladder and urethra, and therefore are the more important This completes the examination

The patient is instructed to drink liberally during the next 24 hours, so that any residues of the contrast medium are washed out of the bladder This precaution has proved efficacious, as roentgenograms obtained 48 hours after the examination in the first 25 cases revealed no evidence of retention of the contrast medium in the bladder, ureters or renal pelves Because of the widespread fear of vesical calculus formation, resulting from retained barium sulphate particles, no patient with a history of recent or earlier urinary infection



Fig 4 Wom n aged 47 ithout genital prolapse or stress ncontinence (group D)

was subjected to the examination and to be certain that no asymptomatic bladder abnormality was present each patient had a cystoscopy performed prior to the cystourethrography The authors though unable to find any proof that barium sulphate particles have ever caused the formation of calculi yet believe the above mentioned precautions advisable

Roentgen dosage The doses in the series were not measured but HAMMER JACOBSEN (1963) stated that the average dose measured in the rectum 8 cm above the anus during cystourethrographies in 18 women in four different roentgen departments was 722 mR (45 to 1 607 mR) The dose at the site of the ovaries was twice as high i e 1 444 mR The average number of exposures was ten

KULD HANSEN (1961) measured the roentgen dose at the site of the ovaries in cystourethrographies in adults and found it to average 270 mR for an

Table 2

Average size of posterior urethrovesical angle (cf table 1)

	Group A	Group B	Group C	Group D
While straining	116 (100—190)	116 ([illegible]0—210)	130° (100—180)	1[illegible]2 (90—180)
During micturition	158 (120—210)	15[illegible] ([illegible]—210)	144° (100—190)	169 (110—180)

average of ten exposures at 120—130 kV, 0 015—0 2 sec exposure time and 1 5 mm Al filter and by diaphragming the beam to film size KJELLBERG et coll (1957), in his series of child cystourethrographies, reported the roentgen dose, measured at the site of the ovaries or testes, to average 9 R (0 5 R per exposure) The number of exposures during the present first 25 examinations was seven (3 frontal, 3 lateral and 1 frontal, 48 hours later) In the remaining examinations the average number of exposures was six (3 frontal and 3 lateral) Prior to the exposures, the patient was screened in the frontal position at 90 kV and 2 mA for an average of 8 sec and in the lateral position at 120 kV and 2 mA for an average of 12 sec The frontal roentgenograms were exposed at 90 kV and 16 mA while the lateral films were obtained at 120 kV and 30 mA The tube was equipped with a 4 mm Al filter and the distance from focus to patient was 10 cm The size of the film was 24 × 30 cm and the beam of rays was always reduced by diaphragming to below film size Compared to the measurements of other examiners the roentgen dosage at the site of the ovaries does not appear to have exceeded the dosage measured in the series of KULD HANSEN

Results

A total of 83 patients were examined but from the roentgenologic point of view the examination was satisfactory in only 68 The main reason for this was gross obesity in 7 patients in whom it was impossible to discern the catheter in the lateral roentgenograms The depression of the bladder base during straining and the size of the urethrovesical angle could therefore not be measured Five patients were unable to micturate standing, and because the examinations were not completed, the results were not included in the final total the result of 3 examinations was unsatisfactory due to faulty processing

The 68 remaining cases were divided into four groups as shown in Table 1 The average age was rather high, one reason being that stress incontinence is most frequently diagnosed in middle age, and another that young patients because of the danger of radiation effect on the ovaries were not subjected to the examination unless their symptoms were severe As many earlier examiners



Fig 5 Woman aged 47 without genital prolapse or stress incontinence (group D) Funnelling present

believe that child birth is an etiologic factor in the development of incontinence, the average number of births in each group is listed

As the depression of the base of the bladder was previously believed to be pathologically increased if it exceeded 10 to 15 mm in frontal roentgenograms during straining it was always measured The distance was taken between the sites of the internal urethral orifices in lateral doubly exposed roentgenogram A cystocele was consequently not registered as an abnormal depression of the base of the bladder

It may also be seen from Table 1 that the average depression does not differ significantly in the four groups if measurement inaccuracy be taken into consideration Surprisingly enough there is an average depression of 16 mm (10 to 35 mm) in the group comprised of normal patients This is in striking contradiction to the earlier belief that a depression exceeding 10 to 15 mm is pathologic and the present examinations therefore give no grounds for the assumption that the extent of the depression of the base in itself is of any particular significance

The normal urethra is constricted superiorly about 1 cm below the base of the bladder This constriction is not always apparent in lateral roentgenograms in stress incontinence and may be replaced by dilatation of the upper part of the urethra or funnelling The frequency of *funnelling* in the different groups is also shown in Table 1 The presence of this phenomenon seems to be a

Table 2

Average size of posterior urethrovesical angle (cf table 1)

	Group A	Group B	Group C	Group D
While straining	146 (100—190)	146 (50—210)	130 (100—180)	152° (90—180)
During micturition	158 (120—210)	155 (45—210)	144 (100—190)	169 (110—180)

average of ten exposures at 120—130 kV, 0 045—0 2 sec exposure time and 1 5 mm Al filter and by diaphragming the beam to film size KJELLBERG et coll (1957), in his series of child cystourethrographies, reported the roentgen dose, measured at the site of the ovaries or testes, to average 9 R (0 5 R per exposure) The number of exposures during the present first 25 examinations was seven (3 frontal, 3 lateral and 1 frontal, 48 hours later) In the remaining examinations the average number of exposures was six (3 frontal and 3 lateral) Prior to the exposures, the patient was screened in the frontal position at 90 kV and 2 mA for an average of 8 sec and in the lateral position at 120 kV and 2 mA for an average of 12 sec The frontal roentgenograms were exposed at 90 kV and 16 mA while the lateral films were obtained at 120 kV and 30 mA The tube was equipped with a 4 mm Al filter and the distance from focus to patient was 40 cm The size of the film was 24 × 30 cm and the beam of rays was always reduced by diaphragming to below film size Compared to the measurements of other examiners the roentgen dosage at the site of the ovaries does not appear to have exceeded the dosage measured in the series of KULD HANSEN

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improves the demonstration of the base of the bladder and urethra in lateral projections There have been warnings against the use of barium contrast media because of the danger of venous reflux, in a personal communication from the distributors of the contrast medium now employed, however, attention was drawn to examinations performed in both human subjects and in animals by Prof Harrison at Liverpool University This investigator was unable to find histologic evidence of any reaction to barium sulphate introduced into the blood system The communication also describes a case in which 20 ml of the barium sulphate contrast medium were inadvertently injected intravenously in a human subject with no consequent untoward effects Therefore, the use of micro disperse barium sulphate as a contrast medium in cystourethrographic examinations should not cause any alarm

The present examinations have not explained why one woman suffers from stress incontinence while another with practically identical roentgenograms remains free The etiologic factors are apparently numerous and no single finding can be said to be pathognomonic of stress incontinence In addition, there is no doubt that the reason for the appearance of stress incontinence is often not organic Nevertheless cystourethrography with a micro disperse barium contrast medium should be performed in all patients suffering from stress incontinence in order to exclude such causal factors as stricture of the urethra tumours diverticulae or fistulae

Acknowledgement

The investigation was aided by a grant from the Foundation for the Promotion of Medical Science

SUMMARY

A method of cystourethrography with a micro-disperse barium contrast medium in a total of 83 patients with stress incontinence is described The significance of depression of the base of the bladder funnelling and the size of the posterior urethrovesical angle are discussed It is concluded that no single sign can be said to be pathognomonic of stress incontinence

ZUSAMMENFASSUNG

Es wird über eine Methode der Cystourethrographie mittels micro-feinverteilten Barium kontrast bei 83 Patienten mit Stressinkontinenz berichtet Die Signifikation der Senkung des Blasenbodens seine Trichterform sowie die Grosse des hinteren urethrovesikalen Winkels werden besprochen Man kommt zu dem Schluss dass keines dieser Symptome an sich pathognomonisch für Stressinkontinenz ist

frequent pathologic finding in cases of stress incontinence and genital prolapse The insignificant difference between groups B and C indicates that funnelling is present just as often in isolated stress incontinence as in isolated genital prolapse, while it apparently is not, as earlier believed, predominantly associated with stress incontinence When stress incontinence and genital prolapse are found together, funnelling seems to be twice as common as when only one of these conditions is present We believe that funnelling may perhaps be regarded as a pathologic phenomenon which often occurs in stress incontinence and genital prolapse when these are found either singly or together

In trying to verify the earlier premise that the posterior urethrovesical angle measured while straining must not exceed about 170°, it was observed that there was no difference between groups A and B either while straining or during micturition (Table 2) It was a matter of some surprise that the average angle in group D was larger than in any other group, but although this group was composed of only 14 patients it is certain that these examinations cannot support the notion that the size of the posterior urethrovesical angle is of paramount importance in the diagnosis of stress incontinence

Discussion

The results obtained by earlier examiners cannot be directly compared to those now reported, as the techniques employed are totally different The degree of depression of the base of the bladder will always be more inaccurate if measured from two superimposed roentgenograms than from doubly exposed roentgenograms Inaccuracy will also occur if the measurement is made in frontal roentgenograms since the distance from the base of the bladder to the film is much more variable in a frontal than in a lateral projection, the reason being the varying obesity of patients Another source of error in measurements in frontal roentgenograms is the frequent presence of small or large cystoceles, which in frontal films cover the base and the internal orifice of the urethra

The rigidity of the catheter inserted into the urethra also constitutes a source of inaccuracy Earlier examiners, who used metal chains or stiff radio paque rubber catheters, have in one way or another altered the normal course of the urethra, and their measurements of the posterior urethrovesical angle cannot therefore have been performed in roentgenograms obtained under uniform conditions The catheters used in the present examinations become very soft when heated to 37° C and therefore can in no way alter the shape or course of the urethra

The use of a micro disperse barium sulphate contrast medium greatly

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RÉSUMÉ

Description d une méthode de cysto urétrographie par un moyen de contraste baryté microdispersé utilisé chez 83 femmes présentant une incontinence d urine à l effort Les auteurs étudient la valeur de la dépression de la base de la vessie de la déformation en entonnoir et de l angle urétro vésical postérieur Ils concluent qu aucun signe isolé ne peut être considéré comme pathognomonique de l incontinence à l effort

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have demonstrated that Diodrast is filtered at the glomerulus and secreted by the renal tubule, while Hypaque® (diatrizoate sodium) is excreted primarily by filtration To compare the relative effectiveness of these two contrast media in the production of a nephrogram during acute bilateral ureteral obstruction each substance was evaluated separately by injecting doses calculated to give 150 mg iodine per kg bodyweight

Method A A total of eleven dogs weighing 7 to 15 kg were used in the first part of these studies After overnight fasting each animal was anesthetized with pentobarbital sodium (30 mg/kg intravenously) Small additional doses were given throughout the experiment when needed Through an abdominal incision both ureters were exposed and sectioned near the renal pelves, and the proximal ends were catheterized with long polythylene tubing One of the following three procedures was then carried out on each dog before occluding the ureteral catheters

1 Water diuresis Five dogs were infused through a venous cannula with a solution of 5 % dextrose in water at a rate of 10 to 15 ml/min until urine flows of 4 to 5 ml per kidney per minute were obtained

2 Osmotic diuresis Three dogs were infused through a venous cannula with a solution of 5 % mannitol in half normal saline at a rate of 10 to 12 ml/min until urine flows of 4 to 5 ml per kidney per minute were obtained

3 Low urine flows (anti diuresis) Three dogs received no intravenous infusion at this point but instead had their catheters elevated until the pressure of the column of urine prevented its excretion

Following any of these three procedures all animals were then treated in an identical manner Both catheters were completely occluded with hemostatic clamps and then a dose of either 0 5 ml Hypaque (50 %) or 0 6 ml Diodrast (50 %) per kg bodyweight was given intravenously Films were taken just before this injection as well as at 5, 15 30 60 and 90 minutes after Both catheters were then released of their obstruction and urine was allowed to flow freely for 1 to 2 hours Occlusion was again repeated and the other contrast medium was injected for comparison with the previous one throughout the same period of time with the same number of films

Method B For the purpose of assaying the accumulation of Hypaque in renal tissue four dogs were studied using only this contrast medium at the same doses as in the other experiments but with radioactive tagged Hypaque ¹³¹I (Abbott) Two of these dogs were treated in an experiment identical with that for osmotic diuresis and the other two as under the low urine flow experiments Thirty minutes after receiving the dose of Hypaque the animals

FROM THE DEPARTMENT OF RADIOLOGY (DIRECTOR PROF HERBERT M STAUFFER), THE DEPARTMENT OF MEDICINE (DIRECTOR PROF THOMAS M DURANT), AND THE DEPARTMENT OF PHYSIOLOGY (DIRECTOR PROF MORTON J OPPENHEIMER), TEMPLE UNIVERSITY SCHOOL OF MEDICINE AND HOSPITAL, PHILADELPHIA, U S A

MECHANISM OF THE NEPHROGRAPHIC EFFECT DURING URINARY STASIS

by

L G BRENES, H FORLANO, N KOUTOURATSAS and H M STAUFFER

During urography under conditions of urinary stasis, as in arterial hypotension or ureteral obstruction, contrast medium accumulates in the kidney and a nephrogram is obtained EDLING et coll (1954, 1957) concluded from their studies that under conditions of stasis the accumulation in the renal tissue occurs through a process of continued uptake by the cells, with subsequent secretion into the lumina of the renal tubules While the interpretation is a logical conclusion for substances primarily excreted through tubular secretion, as with Umbradil® (diethanolamine salt of Diodone, Diodrast®), such a mechanism would be of less importance for substances excreted to a greater extent by glomerular filtration

We have undertaken to explore the role played by glomerular filtration as well as to evaluate the importance of tubular secretion during nephrography To this end we have chosen the dog as experimental animal, previous workers

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have demonstrated that Diodrast is filtered at the glomerulus and secreted by the renal tubule, while Hypaque* (diatrizoate sodium) is excreted primarily by filtration To compare the relative effectiveness of these two contrast media in the production of a nephrogram during acute bilateral ureteral obstruction, each substance was evaluated separately by injecting doses calculated to give 150 mg iodine per kg body weight

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Table 1

Results of all the experiments in 15 dogs with reference to the number of experiments during each procedure that received the grading in question of the nephrographic effect when using two different contrast media

	Diodrast			Hypaque		
	Good	Fair	None	Good	Fair	None
Low urine flow	3	0	0	5	0	0
Water diuresis	2	2	1	2	2	1
Osmotic diuresis	0	0	3	0	0	5

were killed with an overdose of pentobarbital sodium, an arterial blood sample was obtained and the left kidney quickly removed after ligation of the pedicle. Samples of renal tissue weighing 300 to 500 mg were obtained from the cortex and medulla, they were weighed to the nearest milligram, and the radioactivity was measured in a *well scintillation* counter. Tissue water was calculated by weight differences after drying the samples in an oven at 100° C for 24 hours. The concentrations of Hypaque in plasma and tissue were calculated from the specific activity of the injected solution.

Results

The nephrographic quality obtained in the different experiments, with each one of the contrast media, is shown in Table 1, in which are included also the four dogs injected with Hypaque alone. A grading of 'good' has been given to an experiment in which a definite accumulation of a given contrast medium occurred at any time during the procedure. 'Fair' refers to experiments in which there were only nephrographic traces, and 'none' is reserved for the absence of nephrographic signs up to the 90 min film.

As may be seen from Table 1, Hypaque and Diodrast produced equally good-quality nephrograms when no diuresing conditions existed prior to obstruction. It should be emphasized that in the low urine flow experiments both contrast media produced good filling of the pelves as well as a detectable nephrogram within the first 5 to 15 minutes, reaching maximum intensity by the 30 min film. A good nephrographic effect obtained with Hypaque under these conditions is shown in the roentgenogram (b).

It is also evident from Table 1 that the presence of osmotic diuresis prior to ureteral obstruction inhibits the nephrographic effect. It should also be noted that with this procedure no contrast filling of the pelves could be detected with either contrast substance, not even in the 90 min film.



a b

Roentgenograms before (a) and 30 min after (b) infusion of Hypaque

Water diuresis was less reliable than the other two procedures in producing consistent results Two good nephrograms were obtained with both contrast media in the same two animals only a fair nephrographic effect could be demonstrated in two dogs and in the fifth no effect was seen with either of the two contrast media used

The results of plasma and tissue analyses in four dogs are shown in *Table 2* It may be seen that in spite of the fact that these animals were given comparable doses of Hypaque two dogs in the low urine flow experiments had at the end of 30 minutes cleared greater amounts of this substance from their plasma than had the other two dogs It is also evident *from Table 2* that the renal tissue under these conditions was richer in contrast medium than in those under osmotic diuresis When the figures are expressed in terms of tissue/plasma ratios which is a better indication of concentration ability, the difference between the two pairs is even more striking

Discussion

Previous interpretations of the *mechanism* of the nephrographic effect during obstruction have been made under the assumption that glomerular filtration ceases as a consequence of urinary stasis (EDLING et coll 1954 1957) This has led to the inescapable conclusion that any accumulation of contrast

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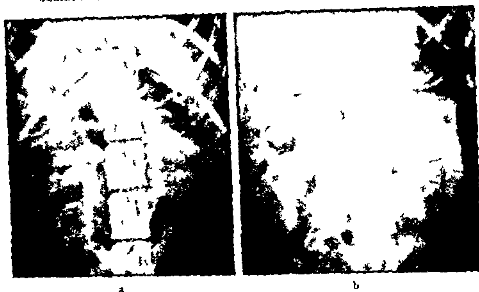
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Table 2

Levels of Hypaque in plasma and renal tissue in four dogs, two of them being obstructed during antidiuresis and two during mannitol diuresis, the analyses being made 30 min after intravenous injection of 250 mg Hypaque per kg body weight

	Antidiuresis		Mannitol diuresis	
Dog No	1	2	1	2
Plasma mg (Hypaque/ml plasma)	0.541	0.526	0.952	0.930
Cortex mg (Hypaque/g dry tissue)	31.60	31.29	12.15	10.68
Medulla mg (Hypaque/g dry tissue)	75.77	36.37	9.53	6.52
Cortex/Plasma	58.40	59.48	12.76	11.50
Medulla/Plasma	140.0	69.14	10.00	7.02

medium in renal tissue during obstruction is produced by cellular uptake and/or secretion into the lumina of renal tubules.

Hypaque has been shown to be excreted primarily or solely by glomerular filtration in the dog (McChesney & Hoppe 1957, Woodruff & Malvin 1960, Stokes et coll. 1962, Blaufox et coll. 1963). Therefore, under the present concept, this substance would not be expected to produce a nephrographic effect in the dog and certainly not one as good as with Diodrast which is known to be secreted by the renal tubules (Smith 1951). Since in our experiments at low urine flows, these contrast media were equally effective when injected at comparable doses of iodine, it follows that another mechanism besides tubular secretion was responsible for the nephrographic effect.

During acute ureteral obstruction, continued reabsorption of water from the lumen by tubule cells decreases the hydrostatic pressure opposing filtration. This allows the entrance of new filtrate into the lumen which displaces the reabsorbed water. Such a mechanism of filtration by displacement was demonstrated by Omachi & Macey (1959), using glomerular filtration indicators injected at different time intervals during stop flow analysis.

Taylor & Ullmann (1961) by similar techniques quantitized the degree in which glomerular filtration continues after acute ureteral obstruction in the dog. They found that obstruction, in the absence of previous osmotic diuresis, allows filtration to continue for as long as one hour at rates of 50% to 75% of those of the unobstructed kidney. Salomon & Lanza (1962), using the disappearance rate from plasma of injected inulin, as well as its recovery from renal tissue, obtained similar figures for rats with bilateral ureteral ligation and for as long as four hours.

TAYLOR & ULLMANN (1961) also showed that when an osmotic diuretic such as mannitol is infused prior to obstruction, the process of filtration by displacement is markedly inhibited. This is presumably due to osmotically acting forces preventing the escape of water that otherwise would diffuse out of the tubule with the reabsorption of sodium.

From the experiments of MURTAGH & GALLOWAY (1960) it would seem that induction of water diuresis prior to obstruction is not as effective in preventing filtration by displacement as is an osmotic diuretic.

All these experiments support our hypothesis that a nephrographic effect during obstruction is due primarily to continued entrance of new filtrate into the lumen with the subsequent reabsorption of water which leads to concentration of the contrast medium within the lumen of the renal tubule. Such a mechanism would explain why Diodrast and Hypaque, although handled differently by the renal tubules of the dog, were equally effective in producing the nephrographic effect. It also could explain why mannitol, an osmotic diuretic not known to compete for the tubular secretory system, inhibited the nephrographic effect of Diodrast as well as that of Hypaque. The partially inhibitory effect observed under water diuresis would fall in line with our hypothesis as suggested by the experiments of MURTAGH & GALLOWAY (1960).

Finally, our plasma and dry tissue determinations of Hypaque demonstrate that the decreased concentration of this substance in the renal parenchyma under osmotic diuresis is due to a decrease in clearance of Hypaque and not merely to a process of dilution brought about by an excess of tissue water.

Although we cannot evaluate the contribution of tubular secretion to the nephrographic effect with Diodrast, its inhibition with mannitol speaks strongly against the importance of such a mechanism. Similar conclusions could be derived from the experiments of EDLING et coll. (1954, 1957) using Umbradil in rabbits. These authors produced inhibition of the nephrographic effect by previously injecting large doses of para amino-hippuric acid (PAH) which they interpreted as a phenomenon of competition for tubular secretion. In view of our observations, we feel that such an interpretation is unnecessary since the large doses of PAH used in these experiments were sufficient to produce an obligatory osmotic diuresis.

SUMMARY

The role of glomerular filtration in the appearance of the nephrographic effect during urinary obstruction was studied in the dog. The relative effectiveness of Diodrast and Hypaque was compared under different states of diuresis prior to bilateral ureteral obstruction. It is concluded that continued glomerular filtration is of main importance for obtaining the nephrographic effect.

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Medulla/Plasma	140.0	69.14	10.00	7.01

medium in renal tissue during obstruction is produced by cellular uptake and/or secretion into the lumina of renal tubules.

Hypaque has been shown to be excreted primarily or solely by glomerular filtration in the dog (Mc Chesney & Hoppe 1957, Woodruff & Malvin 1960, Stokes et coll. 1962, Blaufox et coll. 1963). Therefore, under the present concept, this substance would not be expected to produce a nephrographic effect in the dog and certainly not one as good as with Diodrast which is known to be secreted by the renal tubules (Smith 1951). Since in our experiments at low urine flows, these contrast media were equally effective when injected at comparable doses of iodine, it follows that another mechanism besides tubular secretion was responsible for the nephrographic effect.

During acute ureteral obstruction, continued reabsorption of water from the lumen by tubule cells decreases the hydrostatic pressure opposing filtration. This allows the entrance of new filtrate into the lumen which displaces the reabsorbed water. Such a mechanism of filtration by displacement was demonstrated by Omachi & Macey (1959), using glomerular filtration indicators injected at different time intervals during stop flow analysis.

Taylor & Ullmann (1961) by similar techniques quantitized the degree in which glomerular filtration continues after acute ureteral obstruction in the dog. They found that obstruction, in the absence of previous osmotic diuresis, allows filtration to continue for as long as one hour at rates of 50% to 75% of those of the unobstructed kidney. Salomon & Lanza (1962), using the disappearance rate from plasma of injected inulin, as well as its recovery from renal tissue, obtained similar figures for rats with bilateral ureteral ligation and for as long as four hours.

FROM THE SURGICAL ROENTGENDIAGNOSTIC DEPARTMENT (DIRECTOR DOCENT ROLF KOHLER) AND SURGICAL CLINIC II (DIRECTOR PROF VAINO SEIRO) UNIVERSITY CENTRAL HOSPITAL, HELSINKI, FINLAND

ANGIOGRAPHIC LOCALIZATION OF SUPRARENAL TUMOURS

by

ROLF KOHLER and LARS R HOLSTI

The treatment of phaeochromocytomas and other suprarenal tumours is surgical or in a few instances radiotherapeutic and because of this the exact localization prior to operation or radiotherapy assumes importance It is however useful in the treatment of Cushing s syndrome to know in which of the suprarenal glands hyperplasia or a tumour is located A phaeochromocytoma usually arises from the adrenal medulla but may develop in any region where there is chromaffin tissue for instance para aortally in the abdominal cavity or mediastinum (BJORK *et coll* 1959)

The diagnosis of conditions caused by phaeochromocytoma and cortical tumours will be established from the clinical and laboratory tests (DAHL IVERSEN 1957 von EULER & STROM 1957) The localization of the tumour itself is however possible only with the help of roentgendiagnostic procedures It is true that in cases of phaeochromocytoma the side involved may be determined by selective catheterization of both renal veins with blood sampling for the determination of the catechol amine excretion (von EULER & STROM),

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ZUSAMMENFASSUNG

Die Rolle der glomerulären Filtrierung bei der Erzielung eines Nephrogrammes während Harnröhren Obstruktion wurde beim Hund untersucht Die relative Effektivitat von Diodrast und Hypaque wurden unter verschiedenen Bedingungen von Diurlsie vor der bilateralen ureteralen Obstruktion verglichen Es wurde auf Grund dieser Experimente konstatiert dass eine kontinuierliche glomerulare Filtrierung die Hauptrolle bei der Erzielung eines Nephrogrammes spielt

RÉSUMÉ

Les auteurs ont étudié sur le chien le role de la filtration glomérulaire dans la formation du néphrogramme au cours de l obstruction des voies urinaires L efficacité relative du Diodrast et du Hypaque a été comparée dans diverses conditions de diurèse avant l obstruction urctérale bilatérale De ces experiences les auteurs concluent que c est la filtration glomérulaire persistante qui joue le role principal dans la formation de ce néphrogramme

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Table 1

Cases examined for phaeochromocytoma

Case	Sex	Age	BP	Urinary catecholamines	Angiography	Operation	Histology	Remarks
1	M	17	200/140	400—1200 µg/24 h	Tumour of left suprarenal	Extirpation of tumour and gland	Phaeochromocytoma	
3	M	18	180/110	165—750 µg/24 h	Tumour of left renal hilum	Extirpation of tumour	Phaeochromocytoma	
4	F	42	190/120	280—520 µg/24 h	Tumour of left suprarenal	Suprarenalectomy	Cortical adenoma (Hormonal analysis revealed a high catecholamine content in the tumour)	
7	F	32	240/130	490 µg/24 h	Tumour of right suprarenal	Suprarenalectomy	Phaeochromocytoma	
8	M	19	200/130	130 µg/24 h once	Normal finding	No	—	Final diagnosis hypertonia essentialis
10	M	19	[illegible]/100	380 µg/24 h	Tumour paraaortally on left side	Exploration inoperable radiotherapy	Phaeochromocytoma	Malignant
12	M	45	300/150	40 µg/24 h	Normal finding	No	—	Final diagnosis hypertonia essentialis
[illegible]	M	38	190/130	70—90 µg/24 h	Chronic pyelonephritis no tumour	No	—	Final diagnosis hypertonia essentialis nephrosclerosis
20	F	15	200/160	1800—2000 µg/24 h	Large tumour in right suprarenal	Suprarenalectomy	Phaeochromocytoma	



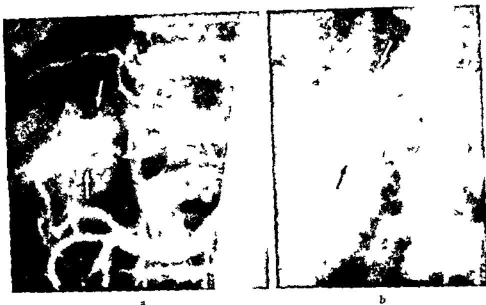
Fig. 1. Aortal suprarenal angiography, nephrographic phase. Normal case. Suprarenal glands located bilaterally at upper poles of kidney and well loaded with contrast medium.

but here again more exact localization and the extent of the process will only be established roentgenologically.

Conventional roentgenography helps but rarely because no more than a few of the *tumours will be distinguishable from the environment without* additional procedures, and calcifications occur infrequently. The kidney is however sometimes displaced, and this may be due to a suprarenal tumour. Urography usually gives no further information. Retroperitoneal pneumography may reveal large tumours of the suprarenal gland although only some of the smaller. GOODWIN, MOORE & PIERCE (1955) and EDSMAN (1957) used combined retroperitoneal pneumography and aortography.

Phaeochromocytomas and cortical tumours are often richly vascularized and may then be demonstrated angiographically. Angiography is in fact by far the best method of localizing suprarenal tumours. The method is not new but has been used surprisingly little (EDSMAN, SUSSE & RADKE 1957, GOODWIN 1961). This is perhaps due to the fear of complications or because the suprarenal glands are not always demonstrable by contrast medium (AHLBACK 1958, MULLER 1962). One of us (HOLSTI 1962) in a previous paper described two phaeochromocytomas demonstrated by aortography. Further experiences form the subject of this report.

Material. Twenty suprarenal angiographies were performed for probable suprarenal tumour from September 1961 to the end of 1962. The injection was made percutaneously from the femoral artery by *inserting the catheter* tip at the level of Th12, 40 ml Urografin 60 % being introduced at a pressure of 5 to 6 kg/cm^2. Nine of the examinations were carried out for probable



F ? Aortal suprarenal ang ography a) Arterial phase Pathologic vessels in an area the size of a thumb tip at upper pole of k dney apparently a ising from the suprarenal artery b) N phrographic pha e Accumulat on of contrast medium in a rounded mass at upper pole of kidney Appea ances suggest a suprarenal tumour histologically a phaeochromocytoma

(430 μg/day) Therapeutic abortion was performed Urography and retroperitoneal pneumography were normal A marked and prolonged fall in blood pressure was produced in the Regitine test A thumb tip sized cluster of pathologic vessels was evident above the upper pole of the right kidney during the arterial phase at aortal angiography (Fig 2a) the tu mour still showed residues in these vessels in the nephrographic phase (Fig 2b) The blood pressure rose to 300 during the injection of contrast medium but immediately fell after the administration of Regitine Four days later both the right suprarenal gland and the tumour w re remo ed (M Turunen) The tumour structure correspon led histologically to a benign phaeochromocytoma although cell polymorphism was fairly considerable The blood pressure remained at about 160 postoperatively

Case 10 Male deaf mute aged 19 with mild attacks of abdominal pain flushing of the face vertigo and vomiting for two years BP elevated (160 120) Urography and retroperitoneal pneumography normal Increased urinary catecholamine excretion (300 to 380 μg hours Angiography revealed pathologic vascularization in a tumour measuring about 7 5 4 5 cm situated between the medial aspect of the lower pole of the left kidney and a medially displaced aorta (Fig 3) No vessel filling was evident at the normal site of the suprarenal gland Exploration (T Rasanen) 5 days later disclosed a tumour measuring 8 4 × 4 cm at the site indi ated in the angiograms It was attached with many thick fibres to the sympathetic plexus and infiltrated both the aorta and the inferior vena cava The branches of the inferior mesenteric artery were also adherent to the tumour mass The

Table 2

Cases examined for cortical hyperfunction

Case	Age	17 ketoster	17 OHCS	Angiography	Operation	Histology	Final diagnosis
5	45	18 mg/24 h	55 mg/24 h	Slight hyperplasia of left suprarenal	Suprarenalectomy (18 g)	Normal	Hyperactivity of suprarenal cortex
6	19	19 2—46 6 mg/24 h (ACTH stress)	24 4—99 mg/24 h	Normal finding	No	—	Cushing s syndr
9	31	22 5 mg/24 h	9 4 mg/24 h	Normal finding	No	—	Hirsutismus
11	27	24 2—35 mg/24 h (ACTH stress)	17 6—60 4 mg/24 h (ACTH stress)	Slight hyperplasia of left suprarenal	Suprarenalectomy (10 g)	Normal	Cushing s syndr
13	23	22 8 mg/24 h	26 4 mg/24 h	Normal finding	*Bilateral* suprarenalectomy (right 7 g left 17 g)	*Cortical* hyperplasia of both suprarenals	*Cushing s* syndr
14	22	38 7—45 8 mg/24 h	16 2—37 4 mg/24 h	*Hyperplasia* of left suprarenal	*Suprarenal*ectomy (16 g)	*Cortical* hyperplasia	*Cushing s* syndr
15	42	14 5—60 9 mg/24 h		Chronic pyelonephritis *suprarenals* normal	No	—	Cushing s syndr
18	22	20 2 mg/24 h	36 5 mg/24 h	Tumour of left suprarenal	Suprarenalectomy (12 g)	Cortical adenoma	Cushing s syndr

phaeochromocytoma and 11 for other suprarenal tumours The main part of the material is presented in greater detail in Tables 1 and 2

Case reports

Case 7 Woman aged 32 who for 4 months had had episodes of headache and vertigo beginning in the third month of pregnancy BP elevated (210/130) no response to treatment Grade I changes were established in the ocular fundi Catecholamine excretion raised



Fig 4 Aortal suprarenal angiography a) Arterial phase Pathologic vessels near upper pole of kidney arising from the aorta and renal artery above the region vessels in the f nix of the stoma h b) Nephrographic phase A rounded lesion 3 5 cm in diameter corresponding to the pathological vascular area Cortical adenoma

Histologically a cortical adenoma The patient received cortisone for 10 days and made a good recovery from the operation

Case 0 A girl aged 15 years complaining of headache and pain behind the eyes of about 12 months duration She had been treated for high blood pressure A month previously she had begun to suffer from sweating thirst and *frequency* of micturition The cerebral symptoms had also increased in bouts and were complicated by vertigo and visual disturbances BP 190/120 Vision in both eyes began to disappear and the patient was no longer able to count her fingers at 1 m hypertensive retinopathy grade IV of ocular fundi BP 200/160 Creatinine clearance was at the lower limits of normal

Urography The right kidney was displaced caudally and secretion was slightly delayed Urinary catecholamine excretion 1 800 to 2 000 μg/24 hours the excretion of vanillic amygdalic acid also elevated The BP fell to 135 in the Regitine test Diagnosis phaeochromocytoma

Angiography Arterial phase roughly parallel tortuous vessels at right angles to the aorta were seen in an area 6 cm in diameter above the right kidney the trunk of these vessels arose from the aorta immediately above the renal artery (Fig 5a) The tumour displaced

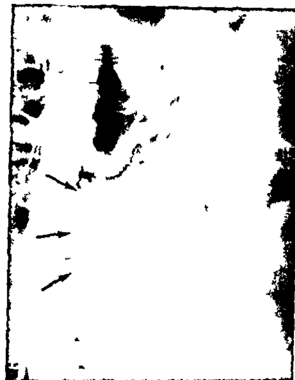


Fig 3 Aortal suprarenal angiography arterial phase A poorly defined space occupying lesion about 7 5 × 4 5 cm in size between the lower pole of the kidney and the infrarenal part of the aorta containing pathologic vessels cranially and medially Malignant phaeochromocytoma

duodenum and jejunum and the middle part of the pancreas were found to be involved The growth was inoperable The suprarenal gland appeared to be normal The tumour was found histologically to be a phaeochromocytoma arising from the chromaffin cells of the symphathetic plexus it was classified as benign

Case 18 Woman aged 22 Menarche at the age of 12 regular menstruation until she was 20 when she commenced to miss periods She had been gaining weight for a year and recently a growth of beard had begun and striae had appeared on both flanks The patient had become all nervous and her ability to concentrate had weakened Definite signs of Cushing s disease moon like facies with redness heavy growth of hair The hairy tegument of the hands and legs was fairly abundant and the pubic hair was masculine Laboratory tests established hyperfunction of the adrenal cortex The urinary 17 OH ketosteroids were elevated ad 36 5 mg 17 ketosteroids were 10 to 14 mg/24 hours Retroperiotoneal pneumography revealed a tumour 3 5 cm in diameter adherent to the upper pole of the left kidney

During the arterial phase of suprarenal angiography pathologic vessels were evident at the site corresponding to the tumour arising from the renal artery and aorta (Fig 4a) What appeared to be a discrete tumour 3 5 cm in diameter, of the left suprarenal gland accumulated a considerable amount of contrast medium in the nephrographic phase (Fig 4b) The right suprarenal was normal in size and also collected contrast medium but the arteries were not separately outlined

The left suprarenal gland was extirpated en bloc two weeks later (O Holopainen) It was the size of a small hen s egg clearly demarcated and weighed 12 g the suprarenal tissue was brittle and tore easily and the cortex appeared to be extremely hypertrophied



Fig 4 Aortal suprarenal ngiography a) Arte ial phase Pathol gic vessels near upper pole of kid ey ar sing from the orta and renal artery above the reg on essels in the forn x of the stomach b) Nephrographic phase A rounded lesion 3 5 cm in d ameter co responding to the patholog c l vascul r area Cortical adenoma

Histologically aortical adenoma The patient received cortisone for 10 days and made a good recovery from the operation

Case 20 A girl aged 15 years complaining of headache and pain behind the eyes of about 12 months duration She had been treated for high blood pressure A month previously she had begun to suffer from sweating thirst and frequency of micturition The cerebral symptoms had also increased in bouts and were complicated by vertigo and visual disturbances BP 190/170 Vision in both eyes began to disappear and the patient was no longer able to count her fingers at 1 m hypertensi e retinopathy grade IV of ocular fundi BP 200 160 Creatinine clearance was at the lower limits of normal

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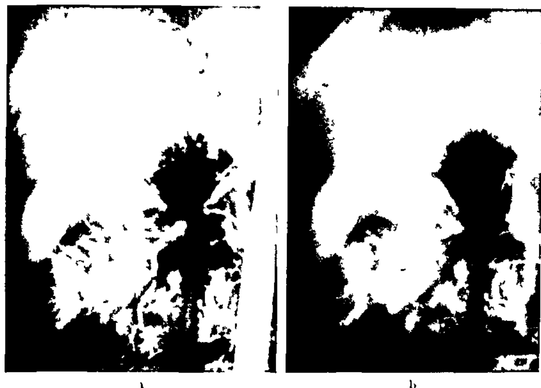


Fig. 5. Aortal suprarenal angiography. a) Arterial phase. Pathologic vessels in a 6 cm area running at right angles to the aorta from a large vessel arising from the aorta close above the renal artery. The kidney is displaced caudally and the renal artery straightened. b) Nephrographic phase. Tumour containing a considerable accumulation of medium above the upper pole of the kidney. Phaeochromocytoma.

the right kidney downwards in such a way that the renal artery had become straightened. The pathologic vascularization was also visible during the nephrographic phase of the kidney (Fig. 5b): a faint suprarenal accumulation of medium was evident in an area of normal size near the upper pole of the left kidney. The patient received 1 mg Regitine intravenously as prophylaxis at the beginning of the examination and the BP remained stable.

The right suprarenal gland and the tumour were extirpated a week later (H. Blomquist). The tumour was encapsulated and its tissue was reddish, brittle, and delimited by the capsule. A wide artery led to the lower pole of the tumour which lay to the right of the vena cava but did not infiltrate it. During its removal the tumour was ruptured and a gelatinous, partly necrotic mass oozed from it; however, the entire pathologic formation was removed piecemeal. Histologically, this was a typical phaeochromocytoma in which no malignant features were apparent. After the operation the patient's headache disappeared, vision improved and the BP remained normal at about 130. Sweating was also considerably reduced.

Discussion

The direct angiographic sign of a suprarenal tumour is the occurrence of tumorous vessels or the demonstration of capillary contrast accumulation in an enlarged suprarenal gland (EDSMAN). Angiography in all 6 phaeochro-

mocytomas and in the cortical adenoma of the present material demonstrated tumorous vessels in which the contrast medium remained longer than in the renal arteries On the other hand blood vessels were not present in the cases of hyperplasia and normal suprarenal glands but there was capillary contrast accumulation

A phaeochromocytoma was considered likely in 9 cases The clinical diagnosis was fairly certain in 6 of these and the catecholamine excretion was distinctly pathologically profuse angiography also revealed the tumour in all these cases The clinical diagnosis was uncertain and the catecholamine excretion normal in 3 cases in which angiography also revealed no signs of tumour

Five of the cases had a characteristic history of periodic headache sweating and blurring of vision The symptoms of Case 7 began during pregnancy which is not altogether uncommon STUTZ et coll (1957) reviewed 21 cases of pregnancy complicated by phaeochromocytoma

One of the present cases was malignant Malignant changes have been reported in 8 to 10 per cent of the cases reviewed in the literature (BARTELS 1959, PALMIERI, IKKOS & LUFT 1961) Only 59 cases of malignant phaeochromocytoma have been published to date and of these the diagnosis was uncertain in 6 cases according to the critical review by PALMIERI et coll The present writers have found no description of a case of malignant phaeochromocytoma demonstrated by angiography

It is to be noted that histologic differentiation is difficult in the diagnosis of malignant phaeochromocytomas because the appearance of benign and malignant tumours may be similar The existence of metastases or local invasions must in fact be regarded as the only reliable criterion of malignancy (BARTELS PALMIERI et coll) There were no metastases in the present case but extensive invasion of the surrounding organs occurred and the tumour was inoperable although the histologic picture was that of a benign tumour Angiography gave an indication of this in that the tumour was irregularly and diffusely outlined All the benign phaeochromocytomas were well demarcated

Cortical hyperfunction or Cushing s disease was probable in 8 cases Angiography revealed a tumour in one case and hyperplasia of one suprarenal gland was probable in 3 cases Cortical adenoma was established operatively and histologically in one of these cases and hyperplasia in 2 cases One case was normal One of the 4 angiographically normal cases was operated on and was found to have a hyperplastic suprarenal gland

Cortical adenomas are generally well vascularized and thus demonstrable angiographically as was also established by EDSMAN AHLBACK The angiographic appearances in cases of cortical hyperplasia are uncertain and it is

difficult to decide whether or not the suprarenal gland is enlarged. The diagnoses in the present series were in fact based on subjective evaluation.

One of the remaining 3 miscellaneous cases was studied for probable hyperaldosteronism, but the angiographic appearances were normal and the patient was not subjected to operation. The second case was examined for an Archard Thier's syndrome; there was evidence of high 17 OH corticoid values, mild diabetes and hirsutism, hyperplasia *or tumour was probable from angio*graphy, but the suprarenal gland removed at operation was histologically normal. The third case, which had metastases of carcinoma in the left thigh, was examined for possible suprarenal carcinoma, but the angiographic appearances were normal.

The risks of angiography in phaeochromocytoma and the necessary precautionary measures have been briefly discussed previously (HOLSTI). Elevation of blood pressure occurred in connection with angiography in 2 cases. It was controlled by immediate intravenous administration of 3 to 5 mg Regitine, given by an anesthetist who was present throughout every examination when there was a probability of phaeochromocytoma. Two further cases were given a prophylactic dose of *1* to 3 mg *Regitine intravenously*. A hypertensive attack during angiography by the catheter method, without more serious sequelae, has been described by EDSMAN, KOONCE, POLLOCK & GLASSY (1952). SALTZ et coll. (1956) and LOPEZ (1958) described hypertensive crises after translumbar aortography, all of which terminated fatally. In addition, of LÉLEK's (1962) 2 cases the one examined by the translumbar technique developed a severe adrenal crisis although the investigation was performed under narcosis; the issue was not fatal, however. The other case was examined by the percutaneous catheter method and no complications ensued.

The writers are of the opinion that the translumbar technique should be *avoided in cases of phaeochromocytoma because of the risks involved*. The aortal catheterization method, in connection with which not a single serious complication has occurred so far, is much to be preferred.

Acknowledgement

This investigation was supported by the Sigrid Juselius Foundation.

SUMMARY

Twenty aortal angiographies were performed for probable suprarenal tumours and 6 phaeochromocytomas, *1* cortical adenoma and *2* hyperplasias were *demonstrated. One of* the phaeochromocytomas was malignant. The method appears to be of definite value in the diagnosis and localization of a phaeochromocytoma or cortical adenoma and in excluding *a tumour in cases of* cortical hyperplasia.

ZUSAMMENFASSUNG

Zwanzig Aortographien wurden unter dem Verdacht auf suprarenale Tumoren ausgeführt sechs *Phäochromocytome ein corticales* Adenom und zwei Hypertrophien wurden entdeckt Ein Phäochromocytom erwies sich als bösartig Die Methode erscheint von grossem Nutzen für die Diagnose und Lokalisierung des Phäochromocytoms und des corticalen Adenoms zu sein oder zum Ausschluss eines Tumours in *Fällen von corticaler Hypertrophie*

RÉSUMÉ

Vingt aortographies *ont été* exécutées pour tumeur probable des surrénales et ont mis en évidence 6 *phéochromocytomes 1 adénome cortical et 2 hyperplasies* Un des phéochromocytomes était malin Cette méthode présente un intérêt certain pour le diagnostic et la localisation des phéochromocytomes ou des adénomes corticaux et pour éliminer une tumeur dans les cas d hyperplasie corticale

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FROM THE EDWARD MALLINCKRODT INSTITUTE OF RADIOLOGY AND THE DEPARTMENT OF MEDICINE WASHINGTON UNIVERSITY SCHOOL OF MEDICINE, ST LOUIS, MISSOURI U S A

CORRELATION OF PULMONARY ARTERY DIAMETER AND PRESSURE IN MITRAL VALVE DISEASE

Angiocardiographic study

by

MARVIN J FRIEDENBERG ARCH W TEMPLETON and BRENT M PARKER

The size of the main pulmonary artery increases in patients with rheumatic mitral valve disease and also in patients with left to right shunts due to congenital abnormalities of the heart or great vessels (3) The estimated size of the main pulmonary artery on conventional roentgenograms of the chest has been correlated with the degree of pulmonary hypertension in patients with rheumatic mitral valve disease (5 6, 8 10 12) but this correlation is not precise Angiography of pulmonary arteries provides more reliable and accurate information regarding the degree of pulmonary hypertension (1, 2, 4) In evaluating venous angiocardiograms in 25 patients SALOFF et coll (1957) found the pulmonary artery diameter correlated 'fairly well with the main pulmonary artery pressure

The purpose of this paper is to report the observed correlation of the pulmonary artery diameter during angiocardiography with the resting systolic

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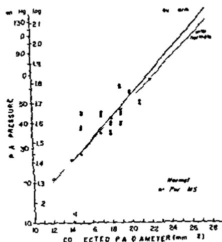


Fig 2 Relationship of pulmonary artery diameter and pressure in normal subjects and patients with mitral stenosis (MS)

The diameter of the main pulmonary artery in ventricular diastole was measured in the films corrected for roentgenographic magnification and expressed per square meter of body surface area using the height and weight of the patient at the time of the examination The calculated diameter was then correlated with the systolic pressure in the main pulmonary artery obtained at rest prior to the injection of the contrast material The pulmonary artery diameter was measured in the lateral projection (Fig 1a) The distance of the pulmonary artery to the left lateral chest wall was measured in order to calculate the magnification correction factor (Fig 1b)

Results

The findings in the 10 normal subjects and in the 56 patients with 'pure mitral stenosis as determined from clinical data catheterization angiocardiography and in 33 patients at surgery are indicated in Fig 2 It shows the relationship of the corrected main pulmonary artery diameter expressed in millimeters per square meter of body surface area, and the resting systolic pulmonary artery pressure in millimeters of mercury The 10 normal patients cannot be compared directly with the others because their mean age was 16 2 years (range 14—18 years) compared to a mean age of 39 1 years (range 17—58 years) for the patients with mitral stenosis Also the normal group comprised 9 males and 1 female whereas the mitral stenosis group included 9 males and 45 females

In all normal subjects and patients with mitral stenosis a statistically significant ($P < 001$) positive correlation was found between the pulmonary



Fig 1 Pulmonary artery angiocardiography in lateral (a) and antero posterior (b) projections The line in (a) indicates the measurement made in the calculation of the pulmonary artery diameter The measurement in (b) is used in the calculation of the correction factor to compensate for roentgenographic magnification

pulmonary artery pressure in normal subjects and in patients with rheumatic mitral stenosis and/or insufficiency

Material and Methods The angiocardiograms of 10 normal patients and 81 patients with rheumatic disease involving predominantly the mitral valve were reviewed In all patients, alternate or simultaneous biplane angiocardiography was performed with the tip of the catheter positioned in the right ventricle or pulmonary artery following a saphenous or antecubital cut down Either the 10 × 12 inch (about 25 × 30 cm) Schonander or 11 × 14 inch (about 27 5 × 35 5 cm) Franklin biplane automatic film changer was used, each having a maximum capacity of 6 pairs of films per second The contrast material was 75 % sodium diatrizoate (Hypaque), 1 3 ml per kg/bodyweight was injected through a No 8—11 NIH catheter (U S Catheter and Instrument Corporation, Glens Falls New York) The Gidlund injector was used at 3 to 7 kg/cm² pressure in order to deliver 25 to 30 ml contrast material per second Pressure recordings were obtained in the right atrium, right ventricle and main pulmonary artery in all patients using a Statham strain gauge transducer Many patients also had pulmonary wedge pressure determinations

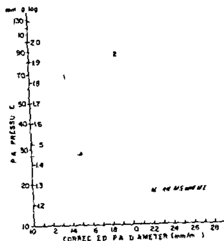


Fig 4 Relationship of pulmonary artery diameter and pressure in patients with mixed mitral stenosis and insufficiency

two exceptions (see Discussion), the pulmonary artery pressure and diameter in this group tended to be small

Discussion

The 10 normal subjects had a calculated pulmonary artery diameter of 14 mm or less and a pulmonary artery resting systolic pressure of less than 28 mm Hg (Fig 2) No patient with pure mitral stenosis had a calculated pulmonary artery diameter of less than 14 mm Four patients with minimal pure mitral stenosis (7 %) had a calculated pulmonary artery diameter of exactly 14 mm but in 3 of these the pulmonary artery pressure was 30 mm Hg or greater Combining these observations it may be concluded that the presence of hemodynamically significant mitral stenosis is highly unlikely in a patient with a calculated pulmonary artery diameter of 14 mm or less and a pulmonary artery pressure of less than 30 mm Hg

In 48 of 56 patients (86 %) with pure mitral stenosis the calculated pulmonary artery diameter was 15 mm or greater and the pulmonary artery pressure was 30 mm Hg or greater Four patients with mitral stenosis (7 %) had a calculated pulmonary artery diameter of 15 mm or greater although the pulmonary artery pressure was less than 30 mm Hg The large pulmonary artery in these patients was a useful sign in interpreting the angiocardiogram and assisted in making the correct diagnosis

Most patients with predominant mitral insufficiency or with 'pure mitral stenosis with associated tricuspid insufficiency (Fig 3) had a pulmonary artery pressure considerably less than would be expected relative to the pulmonary

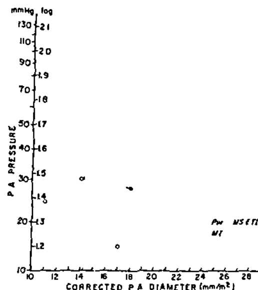


Fig 3 Relationship of pulmonary artery diameter and pressure in patients with pure mitral stenosis and associated tricuspid insufficiency (TI) and in patients with mitral insufficiency (MI)

artery diameter and pressure, i e an increase in diameter was associated with an increase in pressure The rate of increase in diameter was not constant with an increase in pressure, as shown by a highly significant departure from a straight line relationship ($P < 01$) However, the relationship between diameter and pressure could be transformed to a straight line by using the logarithms of the pressures, whether or not the 10 normal patients were included *The correlation coefficient for the pulmonary artery diameter* and logarithm of the pulmonary artery pressure was 0 7852 when all 66 observations were used and 0 6900 when the 10 normal subjects were excluded

The 10 normal individuals had a calculated pulmonary artery diameter of 14 mm or less Four patients with mitral stenosis (7 %) had a calculated *pulmonary artery diameter of exactly 14 mm, and the remaining 52 patients* with mitral stenosis (93 %) had a diameter of 15 mm or greater Four patients of the latter group had a pulmonary artery pressure of less than 30 mm Hg

In Fig 3, the findings in the 7 patients with 'pure' mitral stenosis with associated tricuspid insufficiency, and in the 6 patients with predominant mitral insufficiency are given *In each of these two groups there was an in*sufficient number of patients to form reliable conclusions regarding the relationship of the pulmonary artery diameter and pressure However, in 8 of these 13 patients the pulmonary artery pressure was 30 mm Hg or less

The findings in the 12 patients with mixed mitral stenosis and insufficiency are indicated in Fig 4 *The number of patients in this group was inadequate* to correlate reliably the pulmonary artery diameter and pressure, although from the available data no obvious direct correlation appears to exist With

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artery diameter A relatively low pulmonary artery pressure would be expected in patients with tricuspid insufficiency because the tricuspid insufficiency may decrease right heart output This low pulmonary artery pressure does not necessarily imply a reduction in pulmonary vascular resistance It would appear that the pulmonary artery pressure may be relatively higher in patients with mitral stenosis than in those with mitral insufficiency Only one of 6 patients with pure mitral insufficiency had a pulmonary artery pressure greater than 30 mm Hg This patient also had hypertensive cardiovascular disease and was in congestive heart failure at the time of catheterization

No definite correlation existed between the pulmonary artery diameter and pressure in patients with mixed mitral stenosis and insufficiency (Fig 4) There was a tendency for the pulmonary artery pressure and diameter of these patients to be small, with the exception of two patients (Fig 4, Nos 1 and 2) who were in severe congestive heart failure at the time of the examination

SUMMARY

Cardiac catheterization and angiocardiography were performed in 10 normal persons and in 81 patients with rheumatic mitral stenosis and/or insufficiency The size of the main pulmonary artery was corrected for roentgenographic magnification and calculated per square meter of body surface area and then correlated with the resting systolic pressure in the pulmonary artery Patients with tricuspid or mitral insufficiency tended to have an unusually low pulmonary artery pressure relative to the pulmonary artery diameter

ZUSAMMENFASSUNG

Herzkatheterisierung und Angiokardiographie wurden an 10 Normalpersonen und 81 Patienten mit rheumatischer Mitralstenose und/oder Insuffizienz durchgeführt Infolge der Röntgenvergrösserung wurden die Masse der Pulmonalarterie korrigiert auf Quadratmeter Körperoberfläche berechnet und dann mit dem systolischen Ruhe Blutdruck in der Pulmonalarterie korreliert Patienten mit Tricuspidal oder Mitral Insuffizienz zeigten im Verhältnis zum Diameter einen ungewöhnlich niedrigen Druck in der Pulmonalarterie

RÉSUMÉ

Les auteurs ont pratiqué un cathétérisme cardiaque et une angiocardiographie chez 10 sujets normaux et chez 81 malades atteints de rétrécissement et/ou d insuffisance mitrale rhumatismale Les dimensions du tronc de l artère pulmonaires ont été corrigées pour tenir compte de l agrandissement radiographique puis calculées par mètre carré de surface corporelle et enfin mises en corrélation avec la pression systolique de repos dans l artère pulmonaire Les malades atteints d insuffisance tricuspidienne ou mitrale ont tendance à avoir une pression artérielle pulmonaire très basse par rapport au diamètre de l artère pulmonaire



a

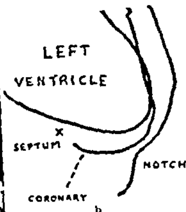


Fig 1 Female aged 8 years with coarctation of the aorta a) Angiocardiography with left ventricular injection The interventricular notch coincides with the lower end of the interventricular septum and the terminal part of the anterior interventricular branch of the left coronary artery b) Schematic diagram

et coll (1953) stated that the appearance of the heart in tricuspid atresia was rarely distinguishable from that of Fallot s tetrad SOULIE (1952) also commented on the similarity of the two conditions WITTENBORG et coll quoted diminished convexity or actual concavity of the right cardiac border as characteristic of tricuspid atresia whereas ASTLEY et coll (1953) observed a similar right cardiac border in 13 of 41 patients with Fallot s tetrad and concluded that this feature was not of diagnostic importance These latter authors also emphasized the significance of the concave middle segment of the left cardiac border in tricuspid atresia BROWN et coll (1956) indicated that there are no constant roentgen appearances of the heart in tricuspid atresia and that the configuration of the heart will generally be compatible with Fallot s tetrad as well KJELLBERG et coll concluded from the roentgenologic viewpoint that it may be difficult to distinguish between the two conditions especially in

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INTERVENTRICULAR NOTCH IN DIFFERENTIAL DIAGNOSIS BETWEEN FALLOT'S TETRAD AND TRICUSPID ATRESIA

by

GEORGE FOO

One of the frequent problems arising in the evaluation of congenital heart lesions is the differential diagnosis between tricuspid atresia and Fallot's tetrad since the clinical findings may be similar in both entities This communication deals with the demonstration of the interventricular notch in conventional roentgenography of the heart, a feature considered helpful in differentiating tricuspid atresia from Fallot's tetrad, the presence of the notch indicates the existence of two functioning ventricles

The demonstration of the interventricular notch in chest films of a patient with Fallot's tetrad was mentioned by KJELLBERG et coll (1959) but its diagnostic significance was not discussed No other reference to its importance has been found There have been numerous comments on the similarity of the roentgenologic findings in Fallot's tetrad and tricuspid atresia WITTENBORG et coll (1951) reported that 9 of 11 patients with tricuspid atresia had a 'coeur en sabot cardiac configuration resembling Fallot's tetrad MARDER

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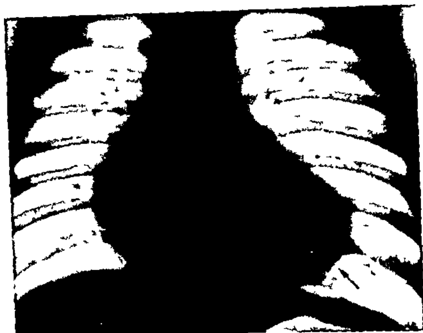


Fig 3 Male aged 4 months with Fallot's tetrad Typical location of the interventricular notch on the lower left cardiac border

with a hypertrophied right ventricle the demarcation constituting the interventricular notch

The notch represents the foreshortened interventricular sulcus as seen in the frontal plane This anatomical explanation for the notch was supported in reviewing the angiocardiograms from patients with two functioning ventricles The notch was seen to coincide in location with the lower end of the interventricular septum and the terminal part of the anterior interventricular branch of the left coronary artery (Fig 1)

Functionally single ventricles would doubtless lack the notch signifying as it does the existence of two functional ventricles A review of the films of 16 patients with functionally single or common ventricles as diagnosed by angiocardiography, supported this concept as no interventricular notch was evident

The chest films of 20 patients with tricuspid atresia and 47 with Fallot's tetrad were examined for the presence or absence of the notch in order to determine the value of the sign All diagnoses were confirmed by selective angiocardiography All the patients with tricuspid atresia, with three exceptions were below the age of four years (6 10, 13 years), a comparative group



Fig. 2 Female aged 4 months with Fallot's tetrad. The interventricular notch is well outlined on the lower left cardiac border.

combination with pulmonary atresia. The shape of the heart is very similar, its size is approximately the same, and the decreased vascularity of the lungs is typical of both conditions. Slight dilatation of the left atrium, however, is not infrequently seen in tricuspid atresia but is rarely found in Fallot's tetrad.

Present study

Fallot's tetrad and tricuspid atresia are both cyanotic lesions with right to left shunts and diminished pulmonary blood flow. In tricuspid atresia the blood shunts across the atrial septal defect as a result of the tricuspid maldevelopment, the right ventricle is either hypoplastic or rudimentary. In Fallot's tetrad there is obstruction to the right ventricular outflow together with right ventricular hypertrophy and shunting across a high ventricular septal defect. Since the right ventricle in tricuspid atresia is hypoplastic and displaced toward the right, no distinct border on the cardiac contour between the left and right ventricles is likely to be present. A distinct demarcation between the ventricles would on the other hand be expected in Fallot's tetrad

of patients with Fallot s tetrad was therefore selected to approximate the same age range Only the frontal films were found to be of value in locating the interventricular notch Films obtained in sufficiently deep inspiration to permit demonstration of the entire left cardiac contour are essential for the demonstration of the notch which when present is readily identified on the left lower cardiac border (Figs 2 and 3) All the patients with tricuspid atresia had an unbroken left cardiac border with no evidence of a notch (Figs 4 and 5) An interventricular notch was present, however, in 15 of the 47 patients with Fallot s tetrad These findings indicate that the absence of the inter ventricular notch does not permit a specific differentiation of these two conditions by this method alone, but when present it is a valuable diagnostic sign

Autopsy examinations of several hearts from patients with these two condi tions substantiated the roentgen findings and indicated that the presence or absence of the notch is also discernible in morbid specimens

Discussion

The interventricular notch was present in approximately a third of the patients with Fallot s tetrad It is noteworthy that the notch was not neces- sarily consistently present in any given patient in the conventional serial exami nations This point was amplified by analysis of the angiocardiograms in which six examples of interventricular notches not discernible in the conventional films were evident The phase of respiration, phase of cardiac cycle, amount of air in the stomach and position of the heart will apparently all influence the roentgen demonstration of the notch it was best and most commonly seen only during ventricular systole The cardiac contour was generally as well delineated in angiocardiograms as in ordinary films

The interventricular notch finds its greatest usefulness in the neonatal period when clinical examination is difficult electrocardiographic findings are equivocal and the prompt differential diagnosis is often critical The total absence of the interventricular notch in patients with tricuspid atresia indicates the significance of its presence

SUMMARY

Radiographic evidence of the interventricular notch is a useful and reliable sign in the differential diagnosis between Fallot s tetrad and tricuspid atresia The notch was observed in approximately a third of the patients with Fallot s tetrad but in none of the patients with tricuspid atresia



Fig 4 Female aged 6 weeks with tricuspid atresia Right atrial enlargement unbroken left cardiac contour no interventricular notch present



Fig 5 Female aged 20 months with tricuspid atresia Right-sided aortic arch unbroken left cardiac contour no interventricular notch present

FROM THE ROENTGENDIAGNOSTIC DEPARTMENT (DIRECTOR PROF GREGERS THOMSEN), COPENHAGEN UNIVERSITY HOSPITAL, DENMARK

SPINAL CORD LESION AS A COMPLICATION OF ABDOMINAL AORTOGRAPHY

Report of 4 cases

by

FRITZ EFSEN

Twenty years elapsed from the description of abdominal aortography by DOS SANTOS LAMAS & CALDAS in 1929 before ANTONI & LINDGREN (1949) reported the first spinal cord lesion as a complication of this diagnostic procedure Several cases have however since been published (BOYARSKI 1954 McCORMACK 1956, HARE 1957 ABESHOUSE & TIONGSON 1956 GROSSMAN & KIRTLEY 1958 ANTHONY 1958 WERTHEIMER 1957) (see Table)

McAFEE (1957) found 29 cases of a spinal cord lesion in an investigation of 13 207 abdominal aortographies five of these were fatal a minimum incidence of 2 in 1 000 KILLEN & FOSTER (1960), in a comprehensive study based on the literature and on questionnaires collected 38 cases including those previously mentioned and a few that have been published in summary form (EVANS 1954 BAURYS 1956) It must be assumed therefore that the actual number of cases is somewhat larger than stated Four that occurred in Danish hospitals during the period 1954 to 1960 may now be added Case 1 has been briefly described by DAMGAARD MOERCK PETERSEN & SANDOE (1957)

Read in part at the 25th Northern Congress of Medical Radiology Odense Denmark 5—8 June 1963 Submitted for publication 7 February 1964

ZUSAMMENFASSUNG

Die Rontgendarstellung der interventrikularen Kerbe ist ein charakteristisches und zuverlassliches Zeichen fur die Differentialdiagnose zwischen Fallotsche Tetrade und Atresie der Trikuspidalklappe Die Kerbe konnte in ungefähr einem Drittel der Falle von Fallotsche Tetrade aber niemals in Fallen von Trikuspidalklappenatresie aufgezeigt werden

RÉSUMÉ

La mise en évidence de l encoche interventriculaire est un signe utile et fidèle pour le diagnostic différentiel entre la tétrade de Fallot et l atrésie triscupidienne Cette encoche a été observée dans environ un tiers des cas de tétrade de Fallot mais ne l a été dans aucun des cas d atresie tricuspidienne

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Case reports

Case 1 Female aged 35 admitted for severe arterial hypertension and a possible pheochromocytoma B P 200/100 the heart was slightly enlarged

Abdominal aortography was performed in the supine position under general anaesthesia The contrast medium 20 ml sodium acetrizoate 50 % (Diaginol®) was injected with a manual high pressure syringe through a polythene catheter introduced by the Seldinger method into the left femoral artery with the tip placed at the level of the second lumbar disk The same evening the patient had paraesthesiae and on the following day had developed incomplete flaccid paralysis The deep reflexes were absent and the Babinski sign was easily elicited on both sides Hypoaesthesia and anaesthesia were present anteriorly from the groins and posteriorly from a level a little below the iliac crest There was some disturbance of micturition but no incontinence These signs were interpreted as being due to a transverse spinal syndrome at L 1 anatomically at the level of D 10

Muscular function improved slightly during the subsequent days Six weeks after the aortography the patient was able to take a few steps and 13 months later she walked with a stick Sensibility was not quite normal Rectal incontinence but some degree of micturition control was present

Case 2 Female aged 25 with a negative history was admitted to a regional hospital with arterial hypertension of 3 months duration B P 235/175 on repeated determinations Ophthalmoscopy disclosed hypertonic fundi grade 3—4 The urine contained a little albumen but no red cells Urea clearance 42 to 43 % serum creatinine 1 0 mg/100 ml Hypotensive medication was ineffective

Urography indicated satisfactory excretion on both sides There was a defect in the right pelvis confirmed by pyelography Retroperitoneal pneumography revealed normal conditions

Abdominal aortography was performed under general anaesthesia with catheterization through the right femoral artery by the method of Seldinger The tip of the catheter was placed at the level of L 3 and 40 ml sodium acetrizoate 70 % (Triopac®) were injected with a manual high pressure syringe However the film changer failed and 35 ml of the same contrast medium were injected 45 min later The B P fell to 170 during the aortography and a pressor drug was administered the B P later rose to extremely high values and hypotensive treatment was given The patient was subsequently found to have a flaccid paralysis of the lower limbs sphincter paresis and anaesthesia from D 8—9 downwards. She developed anuria and died of renal failure 11 days after the aortography without any change in the neurologic signs

At autopsy atheromatous changes in the aorta were noted but no mention was made of subintimal haemorrhages Both kidneys measured 3 5 × 5 × 11 cm The capsule in several regions adhered closely to the surface which was extremely hyperaemic with areas of alternating necroses and minor haemorrhages The cortices measured 7 mm and the medullae 15 mm and there were multiple pyramidal infarctions The gross appearance of the spinal cord was not described

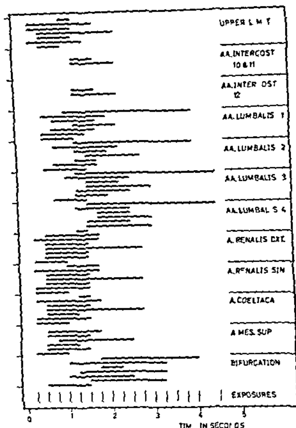
The histologic examination showed streaks of necroses with marginal haemorrhages extending from the cortex into the papillae of both kidneys The arterioles presented thickening of both intima and media. Cross-sections of the lumbar cord revealed large areas of degeneration involving all tracts Only a very few normal nerve cells were present in the grey matter mostly in the anterior horns Numerous red blood cells were evident around the capillaries no thrombosis of the anterior spinal artery

Table

Data of reported cases of spinal cord lesion complicating abdominal aortography

Author	Year of publication	Number of cases	Technique	Brand name	Contrast medium: Concentration W/V %	Test dose* ml	Volume injected ml	Total dose ml
ANTONI & LINDGREN	1949	1	Translumbar	Umbradil®	—	—	—	—
BOYARSKI	1954	1	Translumbar	Urokon®	70	5	10	15
McCORMACK	1956	1	*Direct puncture* of aorta	Urokon®	70	—	15 + 20	35
AHLSHOUSE & TIONGSON	1956	1	Translumbar	Urokon®	70	2	30	32
HARE	1957	1	Translumbar	Urokon®	70	7	45 + 32	84
McAFEE	1957	19	—	11 Urokon®	—	—	—	—
				7 Diodrast®	—	—	—	—
				1 Other media	—	—	—	—
		10		10 Unknown				40
GROSSMAN & KIRTLEY	1958	1	Translumbar	Urokon®	70	1	12 + 10	23
ANTHONY	1958	1	Translumbar	Urokon®	70	—	25	25
WERTHEIMER	1958	1	Translumbar	Diodon	70	—	—	—
KILLEN & FOSTER	1960	38	16 Translumbar 5 Transfemoral 1 Transbrachial 16 Unknown	20 Urokon® 2 Diodrast® 1 Urokon® and Hypaque® 1 Neoiopax® 1 NaJ 13 Unknown	(70)			10 to 84
EFSEN (Present material)	1966	1	1954 All	Diaginol®	50	—	20	20
		2	1955 transfemoral	Triopac®	70	—	40 + 35	75
		3	1958 (supine)	Triiodyl®	70	8.5	30 + 3 × 20	98.5
		4	1960	Triiodyl®	70	—	10	40

* Small dose injected into aorta to verify position of needle or catheter tip



F g 2 Inj ction of sodium acetrizoate 50 in doses between 18 and 30 ml ti ne and duration of visible filling of various arteries in 7 cases subjected to abdominal aortography for non vascula disease

lumbar part of the cord was totally disintegrated and brownish in colour The cauda equina appeared to be normal Widespread focal inflammatory changes from which pus could be expressed were present in th lungs A small infarction was evident in the left basal zone Marked calcification was present in the aortic arch and around the origin of the coeliac artery moderate calcification was noted in the distal branches of the aorta No thrombi or emboli were observed

On histologic examination widespread areas of necrosis both in the white and the grey matter were present in the lumbar part of the spinal cord The sheaths of the roots were degenerated The posterior tracts and one of the lateral tracts also contained areas of degeneration which decreased cranially No thrombosis of the anterior spinal artery was observed.

Case 4 Woman aged 49 admitted to a regional hospital for intermittent claudication with a year s history of pain in the calves after walking 200 m There was no pulsation in the left femoral and dorsalis pedis arteries but faint pulsation in these arteries on the right side

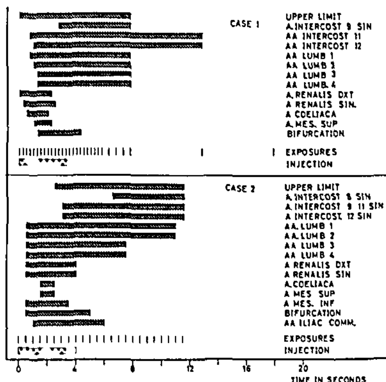


Fig 1 Cases 1 and 2 Passage of contrast medium through various arteries length of time (in sec) during which the contrast medium was seen in a given vessel is indicated the medium was retained for an extraordinarily long time in the intercostal and lumbar arteries

Case 3 Male aged 65 admitted to a regional hospital with intermittent claudication he was able to walk only 50 m without pain No arterial pulsation was palpable below the level of the femoral artery B P 110/90

As vascular surgery was contemplated he was submitted to abdominal aortography under intubation anaesthesia A polythene catheter was introduced into the right femoral artery by the Seldinger method with the tip at the level of L 5 just below the aortic bifurcation Aortography was performed with 30 ml sodium acetrizoate 70 % (Triyodyl®) injected with an automatic pressure syringe and lower limb arteriography with 3 × 20 ml contrast medium injected manually Including the test dose a total dose of 98 5 ml of the medium was thus given

Severe convulsions of the lower limbs and a decrease of the B P from 150/90 to 90/60 immediately followed by an increase to 200/100 maintained throughout the procedure were recorded The patient complained the same evening of numbness of the legs and an inability to move them The signs indicated that there was total anaesthesia up to the level of the umbilicus total paralysis of the lower limbs and loss of sphincter function A total spinal transverse syndrome at the level of D 9 had developed The patient died of bronchopneumonia about two months after the aortography without any change in the neurologic signs

At autopsy the surface of the lumbar cord had a yellowish brown discoloration while the remainder appeared normal A section of the upper part of the spinal cord revealed no changes but more distally an increasing degeneration of the dorsal tracts was apparent the

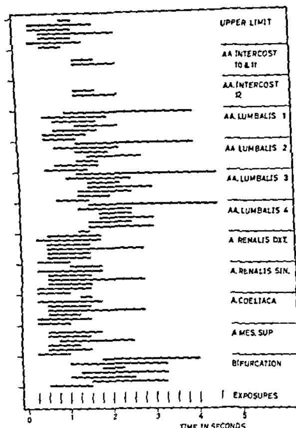


Fig 2 Injection of sodium acetrizoate 50 in doses between 18 and 30 ml time and duration of visible filling of various arteries in 7 cases subjected to abdominal aortography for non vascular disease

lumbar part of the cord was totally disintegrated and brownish in colour The cauda equina appeared to be normal Widespread focal inflammatory changes from which pus could be expressed were present in the lungs A small infarction was evident in the left basal zone Marked calcification was present in the aortic arch and around the origin of the coeliac artery moderate calcification was noted in the distal branches of the aorta No thrombi or emboli were observed

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Case 4 Woman aged 49 admitted to a regional hospital for intermittent claudication with a year s history of pain in the calves after walking 200 m There was no pulsation in the left femoral and dorsalis pedis arteries but faint pulsation in these arteries on the right side

Arteriography of the right femoral artery performed in March 1960 revealed a narrowing below the origin of the deep femoral artery An unsuccessful attempt at left sided arteriography by the Seldinger technique was made two weeks later No neurologic complications occurred on these occasions

A month later abdominal aortography was performed in the supine position under intubation anaesthesia following premedication Shortly after the induction of the anaesthesia the B P fell to 80/60 and a pressor drug had to be administered

The catheter was introduced through the right femoral artery by the Seldinger technique with the tip placed at the level of L 3, 40 ml sodium acetrizoate 70 % (Triodyl®) were then injected with a manual high pressure syringe Immediately before the injection the arterial blood pressure was 120/85 and shortly after it rose from 110/70 to 170/90

The sequence of the three available films has not been recorded The aorta must have been filled with contrast medium to above the origin of the right 11th or 12th costal artery as this vessel is visible in all the films The distance between the *tip of the catheter and the upper* limit of the contrast medium in the aorta is very long and the blood flow through the aorta was therefore probably reduced during the injection The renal and the lumbar arteries were well filled but no contrast medium was evident in the coeliac and superior mesenteric arteries The right common iliac artery *was narrowed and some irregularities of its walls were apparent* The walls of the left common iliac artery appeared smooth but the lumen narrower than normal An occlusion was present in both femoral arteries measuring 6 cm on the right and 3 cm on the left side and situated at the level of the origin of the femoral circumflex and the deep femoral arteries *Dense contrast filling of the vascular system was evident throughout all three films* This indicates an extraordinarily slow passage of the contrast medium as the minimum period that elapsed between the first and the third film was 3 seconds

On recovery from the general anaesthesia the patient was found to have paralysis and anaesthesia *from D 9—D 10 downwards, urinary incontinence, and faecal retention* Twenty seven months after the aortography she was confined to a wheelchair, with marked spasticity of the lower limbs chiefly the right Sensibility was normal above but greatly reduced below the umbilicus

Comments on the case reports

Anaesthesia General anaesthesia was used in all cases during aortography Lowering of the arterial blood pressure was recorded in Cases 2, 3 and 4 In Case 2 it fell from about 235/175 to 170 systolic The blood pressure at the time of the aortography was 90/60 in Case 3, it then rose to 200/100 and changed only little during the subsequent three injections The blood pressure was 110/70 during the injection of the contrast medium in Case 4

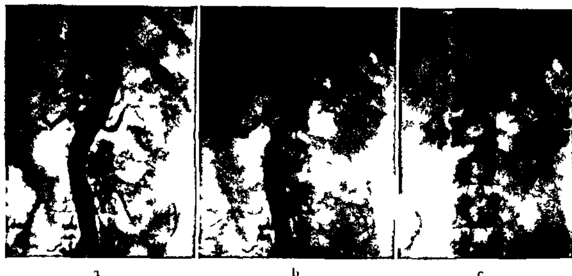
Technique of injection In contrast to the majority of KILLEN & FOSTER's cases, the injections were made in the supine position through catheters The injection period presumably lasted for not more than 3 to 4 sec Sodium acetrizoate (Diaginol®, Triopac®, Triodyl®) was used in all cases, other trade names are Urokon®, Triurol®, Acetiodone®, Rheopak®

a b



c d

Fig 3 Case 1 a) At 0·25 sec b) at 1·75 sec c) at 2·5 sec and d) at 7·75 sec after injection of the contrast medium was started Slow passage of medium through the aorta and its branches



a b c

Fig. 4. Case 2. a) At 1.5 sec, b) at 4.0 sec, and c) at 11.5 sec after the injection of contrast medium was started. Slow passage of the medium through the aorta and its branches.

Roentgen technique. Serial films were obtained with an automatic film changer in all cases. All the films of Cases 1 and 2 were available and some of Case 4. A diagram was prepared from the programmes of the complete series of films in Cases 1 and 2, showing the times of passage of contrast medium through the various arteries. This revealed that the contrast medium was retained in the intercostal and lumbar arteries for a considerably longer period than found in a control series of similar procedures in our department (Figs 1 and 2).

Cases 1 and 2 (Fig. 3, a and b, and Fig. 4, a and b) presented a patchy distribution of the contrast medium in the aorta, indicating a poor mixture. In the later films (Fig. 3, c and d, and Fig. 4 c) the medium was still lodged in the upper part of the abdominal aorta, while there was no visible filling of the lower part. It was stated in the original report on the films in Case 3 that severe atheromatous changes were found in the wall of the abdominal aorta and below the bifurcation. Moreover, obstructive changes were evident in both femoral arteries. There was marked retrograde filling of the abdominal aorta during aortography, and the contrast medium remained for a 'surprisingly long time' around the bifurcation and in the smaller pelvic arteries. This is also mentioned in the report on Case 2. All three films of Case 4 (Fig. 5) displayed marked filling of the entire length of the vascular system from just above the renal arteries down to the popliteal arteries.

According to these observations, the passage of contrast medium must have been extraordinarily slow in all cases. There was no suggestion of a subintimal injection in any of the cases.



Fig 5 Case 4 Abdominal aortography films exposed within 3 0 sec. Distinct filling from upper limit of aorta to small arteries of the thigh

Convulsions Convulsions of the lower limbs were observed during aortography in Case 3 No convulsions had been induced however by the preliminary test dose or by the three injections at subsequent arteriography

Clinical manifestations Lower limb paraesthesiae were manifest in Case 1 about 8 hours after the procedure while incomplete paraplegia did not develop until about 24 hours after aortography Both paraplegia and anaesthesia were present as soon as two of the patients (Cases 2 and 4) had recovered from the general anaesthesia One patient (Case 3) complained 10 to 12 hours after aortography that his legs were numb and paralysed

Death occurred in Case 2 from renal failure 11 days after the procedure, and in Case 3 of bronchopneumonia about two months after aortography

The patient in Case 1 improved considerably and is able to walk with the aid of sticks In Case 4 there is only partial muscle control the patient is disabled by spasticity and can only get around in a wheel chair

Discussion

Various hypotheses have been advanced to explain the cause of this serio complication ANTONI & LINDGREN (1949) discussed the effect of anoxia of th spinal cord owing to compression of the aorta, their patient had been plac on a pillow in order that the aorta should be immobilized during the tran lumbar aortography They refer to Steno's experiment, which showed that rabbits prolonged compression of the aorta causes flaccid paraplegia of th hind part of the body Direct injury to the cord by the needle used in tran lumbar aortography has been mentioned by EVANS (1954) BOYARSKI (195 believed the cause to be thrombosis of the anterior spinal artery, althoug chemical damage could not be ruled out Lately, it has been agreed that th cause must be sought in the effect of contrast media upon either the vessel w or the nervous tissue READ (1959) and JOHNSON & KNISELY (1962), amo others, have pointed out that contrast media may cause agglutination of th red cells, involving the risk of capillary occlusion However, the patholog significance of this phenomenon has not been proved

There was a slow passage of the contrast medium through the aorta, probab due to transient hypotension in the present four cases of a spinal cord lesio The effect of this may have been enhanced by occlusive, atherosclerot changes in two of the cases It is worth noting that the contrast medium use in all the cases was sodium acetrizoate

Anatomical considerations The anterior spinal artery supplies most of th anterior part of the spinal cord, while the smaller posterior part is supplie by small branches running along the posterior roots (WOOLLAM & MILLE 1955) The anterior spinal artery in the thoracic segments receives its bloo supply from a rather small number of frequently unpaired branches along th anterior roots, derived from the intercostal arteries The lumbar cord is sup plied by a frequently unpaired, usually left sided anterior branch which ma be situated at any level between D 8 and L 3 (SUH & ALEXANDER 1939)

According to the previous and the present cases, the spinal cord has bee damaged only in that part which receives its arterial blood supply from th segment of the aorta filled with contrast medium

That the above mentioned arteries do play a role in aortographic cor lesions was shown by LANCE, KILLEN & OWENS (1959) and KILLEN & LANC (1962) in experiments performed to find means of protecting the cord fro lesions due to contrast media All the lumbar arteries in dogs were ligate Those dogs that did not develop paresis were injected with sodium acetrizoat 70 % in doses that invariably give rise to paresis The fact that none of thes dogs developed paresis indicates that they were protected, because blood wa coming from a level where the aorta contained no contrast medium

Contrast media The great majority of spinal cord lesions reported in the literature and three of the present lesions, occurred after the use of sodium acetrizoate 70 % while the first of the present cases occurred with sodium acetrizoate 50 % (cf Table) This indicates that sodium acetrizoate is a more toxic agent than most other contrast media It must be mentioned, however, that the toxic effect of sodium acetrizoate on the central nervous system is only half that recorded with iodopyracet (Diodone) (McAFEE 1957)

The general laws applying to the effect of contrast media upon nervous tissue were investigated experimentally by BROMAN & OLSSON (1948 1949 1956) BROMAN FORSSMAN & OLSSON (1950) and by HOL & SKJERVEN (1954) with the trypan blue method These workers demonstrated that the size of the single dose the time that the contrast medium was in contact with the vessel wall, the concentration of the contrast medium and — owing to the summation effect — the number of previous injections influenced the breakdown of the blood brain barrier Thus all factors that delay the passage of the contrast medium through the vessels of the cord may contribute to causing lesions

The above mentioned experiments were performed with iodopyracet (Umbradil® = Diodrast®) There is every reason to believe however, that the findings apply universally to other similar contrast media

Dosage KILLEN FOSTER & SCOTT (1962) demonstrated that most spinal cord lesions have occurred within the usual dosage range for abdominal aortography (0 2 to 1 0 ml sodium acetrizoate 70 % per kg bodyweight) The single doses were 40 ml sodium acetrizoate 70 % in the present Cases 2 and 4 Regardless of the chemical constitution of the contrast medium, McAFEE (1957) found a considerable increase in the number of neurologic complications when the single dose exceeded 40 ml

Renal damage Sodium acetrizoate has been mentioned in connection with several cases of renal damage even with fatal outcome (CRAWFORD et coll 1957 McAFEE 1957 WYLIE & GOLDMAN 1958 and others) One of the present patients (Case 2) a paraplegic died of renal failure

It has been demonstrated experimentally that sodium acetrizoate, injected into the renal artery causes a considerable and often irreversible impairment of renal function (STOKES & BERNARD 1961) and a decrease of the renal blood flow measured directly (LINDGREN 1961) The dosage in these experiments was however high Both cortical and medullary oedema were present in the kidney after its exposure to sodium acetrizoate The effects of sodium acetrizoate and sodium diatrizoate (e g Hypaque®) were compared in LINDGREN's experiments Just as in investigations of other organ systems the effect of sodium

acetrizoate was far more profound than that of sodium diatrizoate, the latter was tolerated in doses that with other media invariably gave rise to damage

Hypotension The hypotension in Cases 2, 3, and 4 may have been caused by the anaesthesia and/or the contrast medium On intravenous injection (COTRIM 1954, BERNSTEIN et coll 1961), and intra-aortic injection (AMUNDSEN et coll 1956, MOE & CRAVER 1959), the blood pressure may decrease to a degree depending upon the chemistry of the contrast medium Sodium acetrizoate, among the triiodized contrast media, exerts by far the most powerful hypotensive effect which, according to MOE & CRAVER, is very long lasting In LINDGREN & TORNELL's (1958) experiments in dogs there was frequently a maximum increase in the flow in the femoral artery upon intra-arterial injection of sodium acetrizoate, although the blood pressure seemed unaffected This was *presumably because only a relatively small vascular area was exposed to* the agent According to the present case reports, sodium acetrizoate injected into the aorta may apparently reduce the blood pressure to values so low that the flow in the aorta will be perceptibly reduced A lowering of the blood pressure has been recorded through the injection catheter within 10 sec after the injection on aortography with iodopyracet (AMUNDSEN et coll 1956) At this time interval in the present Cases 1 and 2, the contrast medium was still in the vessels supplying the spinal cord

Conclusion

There was a slow passage of contrast medium through the aorta in all the present four cases of paraplegia, and in three of these some degree of hypotension was recorded during the aortography It is probable that sodium acetrizoate and/or the *anaesthesia provoked the hypotension, thereby delaying the passage* of this very toxic contrast medium through the vessels of the spinal cord and resulting in injury to the blood brain barrier With our present knowledge of its toxicity and hypotensive effect, the employment of sodium acetrizoate should be abandoned

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SUMMARY

Four cases of a spinal cord lesion following abdominal aortography with sodium acetrizoate under general anaesthesia are reported Two of the patients died and two are severely disabled by paraplegia A slow passage of the contrast medium and some degree of hypotension were recorded during the examinations The relationship between the contrast medium, hypotension and spinal cord lesion is discussed Sodium acetrizoate should no longer be used

ZUSAMMENFASSUNG

Es wird uber 4 Falle berichtet welche nach abdominaler Aortographie mit Natriumazetrizoat unter Allgemeinnarkose Rückenmarkschadigungen aufwiesen Zwei Patienten starben zwei Patienten wurden durch eine Paraplegie schwer gelahmt Wahrend der Durchfuhrung des diagnostischen Eingriffes wurde eine langsame Stromung des Kontrastmittels und Blutdrucksenkung festgestellt Der Zusammenhang zwischen Kontrastmittel Blutdrucksenkung und Ruckenmarkschadigung wird erortert Natriumazetrizoat sollte nicht mehr verwendet werden

RÉSUMÉ

L auteur présente quatre cas de lésion de la moelle épinière apres aortographie abdominale a l acétrizoate de sodium sous anesthésie générale Deux de ces malades sont morts et deux autres sont rendu gravement infirmes par une paraplégie On a noté au cours de ces examens un passage lent du moyen de contraste et une certaine hypotension L auteur discute le rapport entre le moyen de contraste l hypotension et la lésion médullaire L acétrizoate de sodium ne devrait plus être utilisé

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TWO-NEEDLE OXYGEN MYELOGRAPHY

by

HERMAN LODIN

The fundaments of the technique of oxygen myelography were worked out by LINDGREN as early as 1939. This technique, with either a sub-occipital or lumbar route for the injection of the oxygen, was further described in later publications by ODIN (1953) and LINDGREN (1957). Certain modifications were added by MURTAGH et coll. (1955) and by JIROUT (1958) in the examination of the cervical subarachnoid region. The investigation technique varies and *depends on whether the whole or only certain parts of the spinal column are* to be examined.

LINDGREN (1941), in descriptions on the techniques of oxygen myelography after cisternal and lumbar puncture, respectively, mentioned that an examination of the whole subarachnoid space can also be performed by the introduction of two needles, one in the cisterna magna and the other in the lumbar region. The gas is injected through the lumbar needle while at the same time fluid flows out through the cisternal needle. No changes in the pressure of the subarachnoid space result from this method and the patient has no feeling of discomfort. A prerequisite for the use of this method is, of course, that the process does not involve a large area. As far as appears from the

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literature on the subject, including publications from Serafimerlasarettet (OLEN 1953 LINDGREN 1957) this modification has not been in current use

MUNRO & ELKINS in 1942 published their so called two needle oxygen myelography technique A needle is placed in the lower lumbar region while the position of the upper needle is varied If the entire spinal column is to be examined the upper needle is placed in the cisterna magna The technique is apparently not satisfactory if the upper needle is not placed sub occipitally the clinical level diagnosis can be delusive and the space is limited for subarachnoidal punctures in for instance, the thoracic region where there is a risk of damaging the medulla

Oxygen myelography after suboccipital puncture has however some disadvantages One of them is that by using a fractional gas and fluid interchange the examination often becomes prolonged Another disadvantage exists in cases of suspected total or subtotal block in which only the upper limit of the pathologic process can be located In order to determine the lower limit at the same session a lumbar puncture with injection of gas is necessary, in which case the head must be elevated This procedure has however the disadvantage that the gas already injected rises up to the cranial cavity and causes considerable discomfort It is therefore often necessary in such cases to perform lumbar oxygen myelography at another time This has prompted us for some years to adopt a two needle technique in order to shorten the examination and to avoid repetition

The patient is placed horizontally on the side and lumbar as well as cisternal puncture are performed at once Specimens of fluid are taken from the two puncture sites The head of the patient is then lowered and oxygen is injected continuously through the lumbar needle while the cisternal needle is kept open Observation of the rate of flow of the fluid in the cisternal needle will immediately indicate the existence of any blockage On the assumption that the flow of fluid through the cisternal needle shows a free passage between the lumbar and the cisternal needles oxygen is continuously injected while fluid flows out through the cisternal needle the fluid in the subarachnoid space is thus washed away When gas is flowing out through the cisternal needle, the latter is closed and oxygen is injected at a pressure of 250 to 300 mm of water via the lumbar needle This procedure is followed by the u ual radiographic routine

If during the injection of oxygen through the lumbar needle the flow of fluid through the cisternal needle is not affected or only slightly so the head of the patient should be elevated The fluid is then allowed to flow spontaneously from the lumbar needle and the oxygen is injected again through the latter The lower limit of a block can thus be located The posture of the body

EVANS both give such large normal variations in their index or ratio that with the same size of skull there is room for considerable normal variations in the size of the ventricles. HEINRICH (1941) supposed that no marked variations in the size of the ventricles would be found in normal individuals, and he considered that the great variations found in groups of patients could be due to pathologic intracerebral conditions.

The size of the skull itself also seems to vary largely in patients with cerebral disease. BRUIJN (1959) reported variations in the external cranial width of from 112 to 196 mm, and KRAEMER (1956) found the internal cranial width to be between 151 and 192 mm. The external width varied between 158 and 205 mm in patients with a third ventricle width of 12 mm or more (so called central cerebral atrophy (LONNUM). As in a normal population there are no great variations in the size of the skull (BRYN & SCHREINER 1929, BALSLEV JORGENSEN et coll. 1959, UDJUS 1963) it may be assumed that disease groups show greater variations than normal groups.

This and other questions concerning the relationship between the size of the skull and that of the ventricles appeared to demand investigation. The authors therefore sought to discover (1) whether the external cranial width in a group of patients with cerebral disease differed from the cranial width in normal subjects, (2) whether a correlation between the ventricular and external cranial measurements existed, and (3) whether age or sex had any influence upon the cranial and ventricular measurements.

Material and Methods. The material consisted of 123 males and 100 females aged from 15 to 70, the mean age being 41.9 years in the men and 41.3 in the women. The patients were investigated consecutively in the years 1960 and 1961. All patients were included, except those with obvious hydrocephalus or cerebral tumour. The age and sex distribution in the material is given below.

Age groups	*Men*	*Women*
⩾60	9	10
50—59	35	21
40—49	28	29
30—39	24	17
20—29	15	13
<20	12	10

All the patients were investigated by the following techniques.

1. Encephalography as described by ROBERTSON (1957). The width of the third ventricle, filled with air posteriorly, was measured in the p. a. projec-

tion The septum-caudate line (SC line) was measured in the a p projection, this line is the shortest distance from the attachment of the septum pellucidum in the corpus callosum to the nearest point of the caudate nucleus (ENGESET & LØNNUM 1958) (The measurements were carried out by Engeset)

2 Roentgen examination of the skull with a FFD of 90 cm and measurements of the maximal external roentgenographic width and length

3 Direct measurements with dividers of the maximal external cranial width and length as described by MARTIN (1928) The distribution of the cranial widths in both sexes was as follows

Cranial width (mm) measured with dividers	*Men*	*Women*	*Total*
≥160	25	5	30
155—159	33	13	46
150—159	47	35	82
<150	18	47	65

4 The cranial index was obtained from the width × 100 divided by the length

5 BRYN & SCHREINER's series of normal cases consisting of 11 784 Norwegian soldiers (1929) were used for assessing the normal variations in cranial size in healthy Norwegian males UDJUS has recently (1963) shown that the cranial width in Norwegian soldiers has increased insignificantly since then

With a view to clarify whether the radiologically assessed cranial widths were suitable for correlating with the encephalographic measurements the differences between the former and the widths measured with dividers were determined (Table 1) The difference varied from 6 to 26 mm The average difference was greater in men (18 9 mm) than in women (16 4 mm) and greater in the broader than in the narrower skulls The explanation of the lack of uniformity in the difference between these measurements is clear from Fig 1 The overall roentgenographic enlargement is greater in a broad skull than in a narrow one The cranial width measured roentgenographically in subjects with a similar shape of head will increase in proportion to the true cranial width as measured with dividers The difference between the roentgenographic width of the skull and the true width will vary with the distance of the maximal distance of the head from the film The encephalographic findings have therefore been correlated with the true external measurements

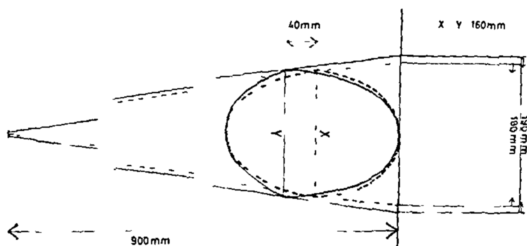


Fig 1 Difference between the cranial width measured radiolographically and the external cranial width measured with dividers *The widths x and y are the same but in the roentgenogram they will differ because the distance of the maximal cranial width from the film varies*

Results

Cranial width The percentage distribution of cranial widths in males and females is shown in Table 2 BRYN & SCHREINER s corresponding figures for healthy Norwegian recruits (1929) are included for comparison The average age of the same recruits today is about 60 years

An obvious tendency towards broader skulls in males is evident in the present material This is especially true in subjects with a third ventricle width of ≥ 8 mm, in whom a cranial width of ≥ 160 mm is about three times as frequent as in BRYN & SCHREINER's material The same distribution of cranial widths as in normal subjects is evident in subjects with a third ventricle width below the suggested upper limit of the normal of 8 mm (DAVIDOFF & DYKE 1946) Women had slightly narrower skulls

Table 1

Differences between the average maximal external cranial width measured in the roentgenogram and with dividers

Cranial width (mm) measured with dividers	Differences in mm		
	Men	Women	Total
>160	21 0	19 3	20 4
150—159	18 4	16 6	17 7
<150	18 3	15 7	16 6
Average	18 9	16 4	17 7

Table 2

Percentage distribution of cranial widths in the present material as compared with that of BRYN & SCHREINER

Cranial width (mm) measured with dividers	Percentage distribution			
	Present material			BRYN & SCHREINER's material
	Men 3rd ventr > 8 mm	Men 3rd ventr < 8 mm	Women	
> 160	27.5	8.5	5.0	8.0
155—159	23.7	31.9	13.0	23.0
150—154	36.8	40.4	35.0	34.9
< 150	11.8	19.1	47.0	34.1

ENGESET & LONNUM's (1958) study of patients with a third ventricle width of ≥ 12 mm confirms that patients with marked ventricular enlargement have relatively broad skulls. The distribution of the maximal external roentgenographic cranial widths in their material, as compared with the corresponding measurements in the present material, will be seen from Table 3. There is a marked tendency towards broader skulls in cases of atrophy. A comparison of Tables 2 and 3 indicates that a third ventricle width of ≥ 12 mm is commonly associated with broad skulls. A cranial width within the variation limit of 25 mm was recorded in 95 % of the material as against 98 % in BRYN & SCHREINER's investigations.

Comparison of cranial and ventricular measurements. The relationship between the true external cranial and the third ventricle widths is shown in Table 4. The width of the third ventricle increases significantly with increasing cranial

Table 3

Comparison of maximal external roentgenographic cranial widths

Cranial width (mm) on film	Percentage distribution	
	Present material (in men)	ENGESET & LONNUM's material
> 180	21.1	0
170—179	49.6	39
< 170	1.1	11

Table 4

Correlation between the maximal external cranial width (measured with dividers) and the width of the third ventricle

Cranial width (mm) measured with dividers	Width of the third ventricle			
	In men		In women	
	Per cent >10 mm	Average	Per cent >10 mm	Average
>160	56	10.4	40	10.7
150—159	24	8.3	19	7.8
<150	11	7.5	13	7.0
Total	28	8.6	17	7.5

width, to the same extent in men and women (correlation coefficients: t for men = 4.58, $P < 0.001$, t for women = 2.42, $P < 0.025$). With a cranial width under 160 mm the width of the third ventricle increases relatively little: about 1 mm per 10 mm increase in cranial width. With larger cranial widths the percentage increase is about the double. The average width of the third ventricle was 8.6 mm in men and 7.5 mm in women, a sex difference of about 1 mm. No such sex difference exists however in groups with the same cranial width. The reason for the difference between the males and females in the investigation is therefore probably the sex difference in the distribution of the cranial widths.

Table 5 shows the relationship between the cranial width and the shortest septum caudate line, with asymmetry the latter is possibly nearer the normal value. An average increase in the SC line of about 1 mm per 10 mm increase

Table 5

Correlation between the maximal external cranial width (measured with dividers) and the shortest septum caudate line

Cranial width (mm) measured with dividers	Septum caudate line			
	Men		Women	
	≥ 15 mm	Average	≥ 15 mm	Average
>160	67	14.8	80	16.1
150—159	36	14.0	42	12.7
<150	17	12.4	36	11.3
Total	39	13.8	41	1[illegible].3

Table 6

Correlation between cranial index and the width of the third ventricle

Cranial index	Numbers	Third ventricle	
		Per cent > 10 mm	Average (mm)
>85	20	40	10.5
80—84	87	28	8.2
75—79	102	20	8.0
<75	14	0	6.4

in cranial width was evident in males The correlation between cranial width and the shortest SC line is obvious in both sexes The greatest increase was found in females with a cranial width > 160 mm The average length of the SC line was 13.8 mm in males and 12.3 mm in females The width of the third ventricle and the shortest SC line measurement presented less correlation with the cranial length and circumference

The relationship between the cranial index and the width of the third ventricle is given in Table 6 The correlation is about the same as that between the cranial and third ventricle widths A correlation between the cranial index and the width of the third ventricle is to be expected since the index increases with increasing cranial width

Age and ventricular measurement Table 8 gives the correlation between the width of the third ventricle and the age of the patient An obvious tendency towards wider ventricles with increasing age is evident particularly in males The tendency is seen both in the percentage distribution of patients with a third ventricle width of > 10 mm and in the average width of the third ventricle

Table 7

Correlation between age and width of third ventricle

Age in years	Width of the third ventricle			
	Men		Women	
	Per cent > 10 mm	Average	Per cent > 10 mm	Average
>50	48	10.6	23	8.6
30—49	21	7.8	15	7.5
<30	11	7.0	13	6.3

Table 8

Correlation between age and the cranial width (measured with dividers)

Age years	Average cranial width	
	Men	Women
≥50	155.2	150.7
30—49	*156.0*	*152.3*
<30	153.4	151.2
Total	155.0	151.6

The *distribution of the true cranial widths in the same age groups is also shown* in this table There is a small increase in cranial width in males in the 30—49 year groups as compared with the 18—29 year group It is therefore unlikely that the difference in width of the third ventricle between different age groups can be explained by an increase in cranial width with age (see Fig 2)

Discussion

Recruits with symptoms and signs of cerebral disease are naturally excluded from military service and BRYN & SCHREINER's measurements therefore indicate the variations in skull size in Norwegian males with apparently normal brains This offered an opportunity to compare the variations in skull size in a pathologic material with that of a normal male population

It was originally presumed that it would be possible to compare BRYN & SCHREINER's findings with the maximal external cranial width measured in roentgen films of patients It was found, however, that the difference between the roentgengraphic and the true widths (measured with dividers) varied too much from patient to patient to form an exact basis for comparison

The range of variation in the maximal cranial width in the present material did not really differ very much from that reported by BRYN & SCHREINER An obvious tendency towards broader skulls, especially in patients with a third ventricle width above normal (≥ 8 *mm*), was however evident This was even more obvious in patients with a third ventricle with ~ 12 mm (LONNUM) A similar tendency to broader skulls was also found in patients with a long SC line

These data seem to indicate that the size of the skull in patients examined by encephalography for some reason or other differs from that in normal subjects BRUIJN (1959) reported findings indicating that some patients have

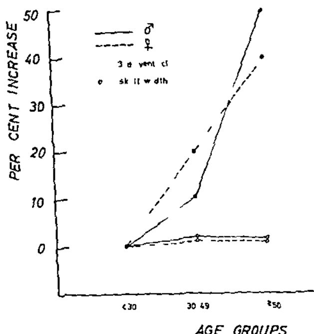


Fig 2 Correlation between age width of skull and width of third ventricle

smaller and others larger skulls than normal It may be assumed that when authors give variations in cranial width in adults greater than those published by BRYN & SCHREINER the relevant patients had pathologic conditions not only in the ventricles but often in the skull as well A pathologic material is therefore obviously not a suitable one from which to draw conclusions about the true relationship between ventricular and skull measurements in normal individuals

A disease material may however give some indication of the average increase in ventricular size with an increase in the corresponding cranial measurements The average width of for example the third ventricle in a large group of patients must depend on its original size, and thus presumably indicate the original relationship It appeared that the increase per 10 mm increase in cranial width in both the width of the third ventricle and the length of the SC line was relatively modest, i e about 1 mm in patients with normal cranial widths (145 to 160 mm) A greater increase was evident in those with relatively large cranial widths (over 160 mm)

NURNBERGER & SCHALTENBRAND (1935) also found an increase of about

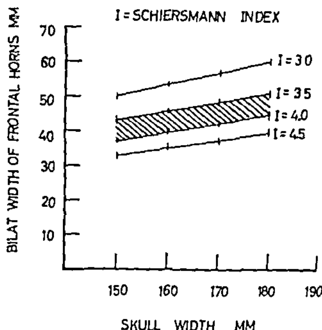


Fig. 3. Variations in bilateral width of frontal horns with SCHIERSMANN's index in people with different widths of the skull.

1 mm in the width of the third ventricle for each 10 mm increase in cranial width in normal subjects. They used a constant size of diaphragm and a FFD of 200 cm. The method of mensuration employed in the present investigation made it unnecessary to use the same tube distance, as the central position of the third ventricle and the cella media precludes the possibility of their being significantly deformed in the roentgenogram through deviation of rays. A correlation between the true measurements of the skull and those of the third ventricle and cella media in the encephalogram will therefore furnish reliable information regarding the relationship between these structures.

It might appear from Schiersmann's index and Evans' ratio that the normal variations in measurements of the ventricles are considerable. If, however, a fixed value is used for the index or ratio — and this is in fact the rule when a decision has to be made as to whether a ventricular system is truly enlarged — *only a small increase in size of the cella media or the frontal horn is present.* This is illustrated in the case of Schiersmann's index in Fig. 3. Similar conditions are also found with the value of Evans' ratio which is said to indicate a definite and pathologic enlargement of the ventricles ($\geqslant 0.31$).

Evans' ratio, Schiersmann's index, Nurnberger & Schaltenbrand's tech

nique and the methods now described thus all lead to approximately the same results as regards the average increase in ventricular measurements per 10 mm increase in cranial width There is, in other words only a slight increase in the width of the third ventricle and length of the SC line with increasing cranial width It is found simpler to use a correlation factor that gives the increase in third ventricle width per 10 mm increase in cranial width rather than to employ an index or ratio which really says the same thing only in a more complicated way This applies to widths of the skull within the normal variation range (135—160 mm)

Definite conclusions about the normal relationship between the cranial and third ventricle widths cannot be drawn in cases of very broad skulls (160—165 mm or more) LONNUM often found signs of latent hydrocephalus or other developmental anomalies in such instances

STERTZ (1938) and PENNYBACKER (1940) also noticed that subjects with relatively large heads had developmental anomalies or a hydrocephalic condition DECHAUME & BOURRAT (1950) often found an above normal cranial size in patients with an enlarged ventricular system who at an age between 40 and 60 years developed symptoms of organic brain disease These authors considered that the ventricular enlargement probably depended until then upon a latent hydrocephalus and other French authors i e THIEBAUT (1946) GUILLET (1948) GIRARD & SCHOTT (1950) and ROGER et coll (1950) were of the same opinion The third ventricle in particular was reported enlarged (BRENNER 1952 GARDE & LEVY 1950) The possibility of anomalies or hydrocephalus should therefore be considered before a diagnosis of cerebral atrophy is made in patients with very broad skulls (160—165 mm true 185 mm in the film)

Variations in the size of the ventricle greater than those corresponding to the variations in the skull measurements found by BRYN & SCHREINER are unlikely in normal subjects A difference in cranial width of 25 mm means according to NURNBERGER & SCHALTENBRAND and the present findings a maximum difference in width of the third ventricle of 2 5 mm A variation of the third ventricle width and of the SC line of about 2 mm has been presumed in the present material for technical reasons Large variations as a result of normal variations in the size of the skull alone would therefore not be expected

A source of error in using fixed measurements in the assessment of encephalographic findings in cerebral atrophy may of course exist This may lead to the atrophy being over estimated in relatively broad skulls and under estimated in narrow skulls Furthermore cerebral atrophy may be present in relatively narrow skulls without the ventricular size approaching a pathologic value The diagnosis of cerebral atrophy must in any event not be based upon the

same absolute measurements in women as in men, as the former generally have smaller cranial widths.

The length of the skull, the circumference of the head, and the cranial index, all present less correlation with the ventricular measurements than the cranial width. No advantage therefore exists in using these values for correlating the encephalographic findings with the skull measurements, at any rate not as long as measurements of the ventricles are made in the a. p. projection.

The width of the third ventricle bore a definite relationship to age. No increase of the cranial width that could explain this was evident in the material although some insignificant growth of the skull may apparently occur in adults (BUCHI 1950, GETZ 1960).

It is questionable whether the increase with age in the width of the third ventricle is due to a normal age involutional process. KNUDSEN (1958) found that 33 % of the lateral ventricles from the brains of normal subjects between 70 and 90 years of age belonged to the same size groups as 90 % of the lateral ventricles from subjects between 20 and 50 years of age.

Conclusions

An obvious tendency to broader skulls was evident in patients of a disease material with a third ventricle width above normal (i. e. more than 8 mm) and with a long septum caudate line (longer than 15 mm). A group of normal Norwegian males acted as a control.

The average increase in width of the third ventricle per 10 mm increase in cranial width was moderate and in patients with a cranial width within normal limits (135—160 mm true, 155—180 in film) it was about 1 mm. The average increase in length of the 'septum caudate' line was almost the same. A correlation factor for the width of the third ventricle and the length of the septum caudate line of about *1 mm per 10 mm increase in width of the skull* is therefore suggested in such patients.

A somewhat greater increase was evident in patients with a cranial width above normal (160—165 mm true, 185 mm in film). The possibility of cerebral anomalies or a hydrocephalic condition of an earlier date must be considered in such instances. The relationship between the skull and the ventricles is not the same as in normal subjects.

A definite correlation between the age and the average width of the third ventricle was found to exist. No increase in cranial width with increasing age was apparent. *The increase in size of the ventricles with age is possibly greater in a disease material than in a normal series.*

SUMMARY

True cranial measurements in 123 males and 100 females were correlated to measurements of the cerebral ventricles in the encephalograms of these patients A relationship was found to exist between the width of the skull and the width of the third ventricle and the length of the septum-caudate line

ZUSAMMENFASSUNG

Die korrigierten Schadelmasse wurden mit den Massen der luftgefullten Gehirnventrikel bei 123 Mannern und 100 Frauen verglichen Ein festes Verhaltnis wurde zwischen der Schadelweite und der Weite des dritten Ventrikels und der Lange der Septum Nucleus caudatus Linie festgestellt

RÉSUMÉ

Les mesures réelles du crane ont été comparées aux mesures sur les encephalographies des ventricules cérébraux de 123 hommes et de 100 femmes On a trouvé une relation entre la largeur du crâne et la largeur du troisième ventricule et la longueur de la ligne septum noyau caudé

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FROM THE ROENTGENDIAGNOSTIC CLINIC (ACTING DIRECTOR B LILIEQUIST) UNIVERSITY OF UMEA, SWEDEN

GAS MYELOGRAPHY IN THE CERVICAL REGION

by

BENGT LILIEQUIST

The routine examination of the cervical subarachnoid space is performed in Sweden with gas myelography by the method described by LINDGREN (1954) The gas is usually introduced suboccipitally although the space may also be investigated with gas introduced in the lumbar region (MURTAGH et coll 1955 LOWMAN & FINKELSTEIN 1942 GREITZ 1964 JIROUT 1958 1959 1961, ROTH 1963 and others) Oily contrast media are in most other countries preferred to gas for myelography (SHAPIRO 1962 DECKER 1960, WELLAUER 1961)

The literature contains no detailed description of the normal appearances of the subarachnoid space in the cervical region examined by gas myelography Changes due to expansive processes were described by LINDGREN (1954), ODÉN (1953) JACOBSEN (1956), and LOWMAN & FINKELSTEIN, and the appearances of the spinal cord in syringomyelia by KLEFVENBERG & SALTZMAN (1959) Cervical disk protrusions cause changes in the subarachnoid space which were described by LINDGREN and also discussed by JACOBSEN JIROUT drew attention to the mobility of the cervical spinal cord and measured its degree in a certain number of normal cases The sagittal diameter of the spinal cord in gas

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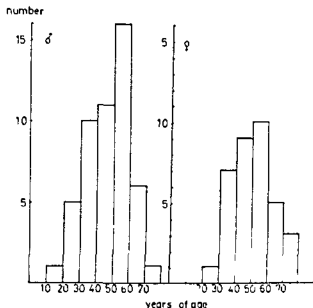


Diagram 1. Age distribution in males (left) and in females (right).

myelograms was investigated by LOWMAN & FINKELSTEIN as well as by KLEFVENBERG & SALTZMAN. The bony spinal canal was measured in its sagittal dimension in roentgen films by BOIJSEN (1954), WOLF, KHILNANI & MALIS (1956), PAYNE & SPILLANE (1957), and BURROWS (1963).

The shape and depth of the cervical subarachnoid space, as evident in gas myelograms, have not been investigated previously in any detail; this is also true of the appearances of the dentate ligaments.

The sagittal dimension of the spinal canal is related to the neurologic signs caused by disk protrusions. PAYNE & SPILLANE found a difference in the width of the bony canal in patients with paraplegia and cervical spondylosis as compared with those who had no abnormal signs. BURROWS reached the same conclusions in an investigation founded upon measurements of the bony canal. Such measurements can only be performed with the aid of a contrast medium that completely fills the subarachnoid space and this cannot be achieved with oily contrast media. Gas will simultaneously demonstrate both the anterior and posterior borders of the subarachnoid space.

Sagittal depth of the cervical subarachnoid space. The sagittal dimension of the cervical subarachnoid space has been measured in 85 gas myelograms. A material composed entirely of normal patients or subjects without clinical signs is not obtainable, as gas myelography can hardly be performed in the absence of symptoms. An attempt has been made to estimate the true dimensions of the space, regardless of local changes in the soft tissues, since the

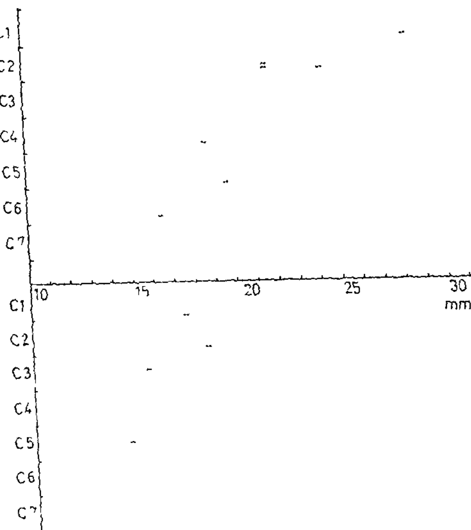


Diagram 2 Width of spinal canal (upper diagram) and subarachnoid space (lower diagram) at the level between C1 to C7

general shape must be independent of any local changes if these are not included in the measurements The measurements have therefore been performed irrespective of pathologic changes in the form of disk protrusions or atrophy of the spinal cord Care has been taken not to measure the width of the space at the level of a disk protrusion

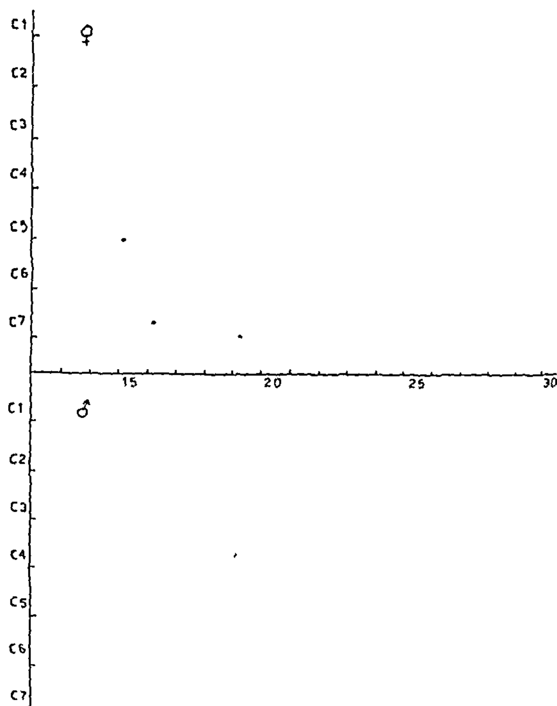
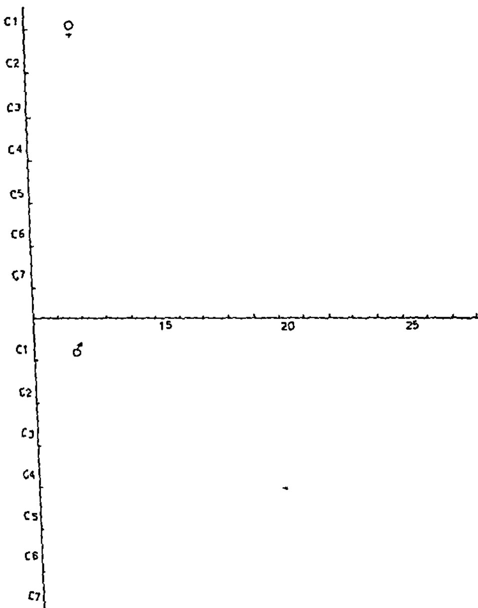


Diagram 3 Widths of the spinal canal (above) and of the subarachnoid space (diagram on opposite page) in males and females at each level from C 1 to C 7



C1
C2
C3
C4
C5
C6
C7
♀
15
20
25
C1
C2
C3
C4
C5
C6
C7
♂

The material consisted of 50 men and 35 women, of ages ranging from 19 to 79, the majority being between 30 and 60 years of age The distribution according to age is seen in Diagram 1

The depth of the spinal canal as well as that of the subarachnoid space were measured The measurements were made on tomographic films at the midline of the vertebral bodies and the corresponding spinal processes The measurements of the canal were taken in the way described by BURROWS, i e the distance from the posterior cortical border of the middle of the vertebral body to the cortical border of the corresponding spinal process was measured The depth of the subarachnoid space was measured at the same level and at right angles to the long axis of the canal The measurements included the subarachnoid space and spinal canal in the cervical region All the examinations were made with a Siemens tomograph, the FFD being 1 40 m, no correction for the degree of magnification was made

The results of the measurements are given in Diagram 2 It is evident that the subarachnoid space as well as the spinal canal are widest at the level of the body of the first cervical vertebra and that they commence to diminish at the level of C2 The width of the subarachnoid space is fairly constant from the level of C3, and caudally to the level of C7 According to BURROWS, the canal successively narrows in its sagittal diameter from C1 to C4 and is of a constant depth from C5 to the upper thoracic region, this has also been observed in our material

A difference between sexes in the width of the spinal canal as well as that of the subarachnoid space is evident, the width being less in females than in males (Diagram 3), this difference is statistically significant A closer study of each case reveals that the relationship of the subarachnoid space to the width of the spinal canal varies caudally to C6 As to the appearances of the subarachnoid space, three different types may be recognised widening, narrowing, and constant width The three types are illustrated schematically in Fig 1

KLEFVENBERG & SALTZMAN have reported that the sagittal width of the cord varies it measures 11 mm at the level of C1, 10 mm between C2 and C6, and 9 to 7 mm caudally to C6 Close agreement with these measurements was reached in the present material, there was no widening of the cord corresponding to the cervical intumescence, and there was consequently no narrowing of the subarachnoid space due to enlargement of the cord Any narrowing of the caudal portion of the space is accompanied by a corresponding narrowing of the cord

The measurements disclose that both the spinal canal and the subarachnoid space are narrower in females than in males The space is widest at the level of C1 and narrows at the level of C2, from C3 caudally to the level of C7

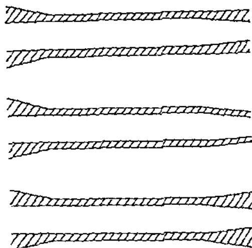


Fig 1 Schematic drawing showing three different types of relationship between the subarachnoid space and spinal canal

it is generally of uniform depth and as it passes into the thoracic region it either becomes adapted to the shape of the cord or widens The subarachnoid space in relation to the cord is thus narrowest from the levels of C3 to C7

Shapes of anterior and posterior borders of cervical subarachnoid space The anterior as well as the posterior aspects of the subarachnoid space in the cervical region may be well demonstrated in gas myelograms The shape of the space posterior to the upper part of the spinal cord below the foramen magnum has been described by the present author in an earlier publication (1959) This part is always outlined in a properly performed gas myelography The posterior border follows a straight line connecting the anterior aspect of the arch of the atlas with the posterior rim of the foramen magnum in the midline (Fig 2) at this level the cord bows anteriorly A large triangular space which in fact is an extracranial part of the cisterna magna cerebello medullaris is thus created The subarachnoid space always bulges more or less posteriorly below the arch of the atlas between it and the arch of the axis (Fig 3) it narrows at the level of C2 and caudally the posterior aspect follows a straight line in close connection with the cortex of each spinal process If the examination is performed with the spine in ventral and dorsal flexion no change in the shape of the posterior border of the subarachnoid space in the form of an indentation can be seen (Fig 4)

Large indentations in myelograms obtained with oily contrast media bulging from behind into the space in the interspaces between the spinal arches

The material consisted of 50 men and 35 women, of ages ranging from 19 to 79, the majority being between 30 and 60 years of age. The distribution according to age is seen in Diagram 1.

The depth of the spinal canal as well as that of the subarachnoid space were measured. The measurements were made on tomographic films at the midline of the vertebral bodies and the corresponding spinal processes. The measurements of the canal were taken in the way described by BURROWS, i.e. the distance from the posterior cortical border of the middle of the vertebral body to the cortical border of the corresponding spinal process was measured. The depth of the subarachnoid space was measured at the same level and at right angles to the long axis of the canal. The measurements included the subarachnoid space and spinal canal in the cervical region. All the examinations were made with a Siemens tomograph, the FFD being 1.40 m; no correction for the degree of magnification was made.

The results of the measurements are given in Diagram 2. It is evident that the subarachnoid space as well as the spinal canal are widest at the level of the body of the first cervical vertebra and that they commence to diminish at the level of C2. The width of the subarachnoid space is fairly constant from the level of C3, and caudally to the level of C7. According to BURROWS, the canal successively narrows in its sagittal diameter from C1 to C4 and is of a constant depth from C5 to the upper thoracic region; this has also been observed in our material.

A difference between sexes in the width of the spinal canal as well as that of the subarachnoid space is evident, the width being less in females than in males (Diagram 3); this difference is statistically significant. A closer study of each case reveals that the relationship of the subarachnoid space to the width of the spinal canal varies caudally to C6. As to the appearances of the subarachnoid space, three different types may be recognised: widening, narrowing, and constant width. The three types are illustrated schematically in Fig. 1.

KLEFVENBERG & SALTZMAN have reported that the sagittal width of the cord varies; it measures 11 mm at the level of C1, 10 mm between C2 and C6, and 9 to 7 mm caudally to C6. Close agreement with these measurements was reached in the present material; there was no widening of the cord corresponding to the cervical intumescence, and there was consequently no narrowing of the subarachnoid space due to enlargement of the cord. Any narrowing of the caudal portion of the space is accompanied by a corresponding narrowing of the cord.

The measurements disclose that both the spinal canal and the subarachnoid space are narrower in females than in males. The space is widest at the level of C1 and narrows at the level of C2, from C3 caudally to the level of C7



Fig 4 Ventral (a) and dorsal (b) flexion of spine No change in the posterior aspect of subarachnoid space

mainly behind or anterior to these structures This is apparent particularly when tomographic views are obtained of this part of the subarachnoid space Formation similar to those said to be caused by indentations of hypertrophied ligamenta flava are demonstrated in the gas myelogram in Fig 5, they are doubtless caused by the dentate ligaments and the nerve roots Posteriorly the outline is always linear in gas myelograms

The anterior border of the subarachnoid space at the level of the axis may be followed upwards into the cranial cavity The soft tissues posterior to the odontoid process are rather thick due to the transverse axial ligament The anterior border is also affected by the axis, the shape of which varies posteriorly The subarachnoid space lies close to the posterior borders of the vertebral bodies and bridges the intervertebral disks without any appreciable deforma



Fig 2 Shape of subarachnoid space below foramen magnum arrows indicate the posterior aspect



Fig 3 Local bulge posteriorly in the subarachnoid space between arches of atlas and axis

have been described and considered to represent hypertrophied ligamenta flava According to SHAPIRO even normal ligamenta flava, at least in hyper extension of the neck, may give rise to indentations in the subarachnoid space Photographs illustrating these indentations indicate that the examinations had been performed with the subjects prone, in which position oily contrast media will become located in the anterior part of the subarachnoid space, anterior to the dentate ligament and the nerve roots, and will not reach the posterior part It is clear that under such conditions there is no possibility of demonstrating indentations from behind

BREIG investigated the behaviour of the dura mater in cadavers in different positions of the spinal canal He could find neither deformation of nor indentations in this part of the dura mater into the subarachnoid space, in different postures of the head and spinal column The true explanation is that these indentations are not due to hypertrophied ligamenta flava but represent anatomical details in the subarachnoid space, namely nerve roots and a normal dentate ligament delimited posteriorly by the oily contrast medium The same anatomical details may be evident in gas myelograms when there is incomplete filling of the subarachnoid space and the gas collects

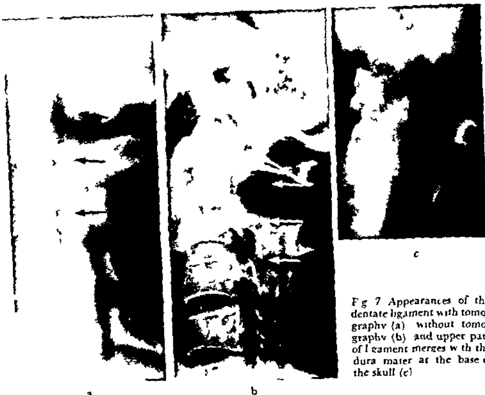


Fig 7 Appearances of the dentate ligament with tomography (a) without tomography (b) and upper part of ligament merges with the dura mater at the base of the skull (c)

gaps in the ligaments gas may pass freely anteriorly even when injected posteriorly and fill up the whole subarachnoid space The dentate ligament in the upper cervical region is short and thick and runs almost perpendicularly from the pia to the dura mater It is attached above to the latter at the anterior border of the foramen magnum and merges into the dura mater along the side of the clivus caudally the ligament is longer and narrower and describes a more oblique course The ligament is attached to the whole length of the spinal cord down to the conus terminalis

The upper part of the dentate ligament is represented in myelograms with oily contrast media as a narrow straight translucent band (SHAPIRO) In gas myelograms the upper part of the ligament is usually seen as a fine straight line that can be followed as it enters the cranial cavity It is best demonstrated in tomograms centered lateral to the midline but may also be distinguished in conventional films (Fig 7) The ligament may occasionally be followed through the whole length of the cervical spinal cord as far down as the conus terminalis (Fig 8) When the subarachnoid spaces are incompletely filled



Fig 5 (above) Incomplete gas filling of subarachnoid spaces simulating local deformities of spinal cord

Fig 6 (right) Small local bulges of intervertebral disks posteriorly appear in hyperextension (a) but disappear in flexion (b)



Fig 6a

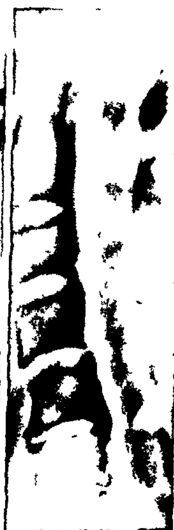


Fig 6b

tion although small local bulges appear when the neck is extended (Fig 6), as examinations in extreme hyperextension are not normally performed these bulges are not often seen

Ligamentum denticulatum The two dentate ligaments emerge on either side from the pia mater midway between the nerve roots and are attached to the dura mater slightly ventrally to the midline of the spinal canal Each ligament consists of a fibrous sheet interrupted at the level of each pair of nerve roots BREIG stated that these ligaments may be stretched in cadavers in certain positions of the spinal column, the cord being lifted from the posterior portion of the spinal canal in ventroflexion and in the supine position As there are

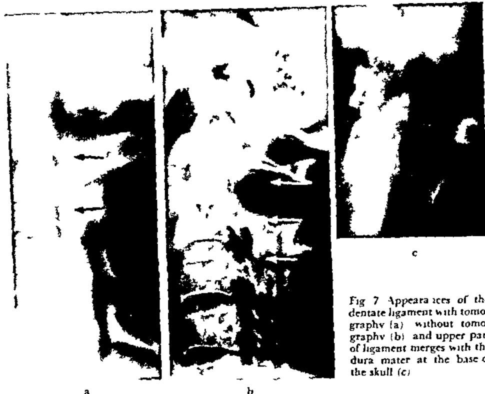


Fig 7 Appearances of the dentate ligament with tomography (a) without tomography (b) and upper part of ligament merges with the dura mater at the base of the skull (c)

gaps in the ligaments gas may pass freely anteriorly, even when injected posteriorly and fill up the whole subarachnoid space The dentate ligament in the upper cervical region is short and thick and runs almost perpendicularly from the pia to the dura mater It is attached above to the latter at the anterior border of the foramen magnum and merges into the dura mater along the side of the clivus caudally the ligament is longer and narrower and describes a more oblique course The ligament is attached to the whole length of the spinal cord down to the conus terminalis

The upper part of the dentate ligament is represented in myelograms with oily contrast media as a narrow straight translucent band (SHAPIRO) In gas myelograms the upper part of the ligament is usually seen as a fine straight line that can be followed as it enters the cranial cavity It is best demonstrated in tomograms centered lateral to the midline but may also be distinguished in conventional films (Fig 7) The ligament may occasionally be followed through the whole length of the cervical spinal cord as far down as the conus terminalis (Fig 8) When the subarachnoid spaces are incompletely filled



Fig 8 Appearance of the dentate ligament in lower thoracic region





Fig 9 Kyphosis Lateral view (left) obtained with vertical beam direction shows the spinal cord to lie anteriorly in the subarachnoid space In supine position (right) the spinal cord has moved backwards

with gas, the ligaments are sometimes delimited on one side by the gas, an appearance that may be mistaken in tomograms for a narrowing of the spinal cord, as pointed out by JIROUT

The cervical spinal cord, in gas myelography properly performed, is surrounded by gas dorsally as well as ventrally It is not unusual to find that a circumscribed part of the cervical spinal cord lies anteriorly in the subarachnoid space and prevents the gas from filling it anteriorly, this often happens in kyphosis (Fig 9) When the patient is turned into supine position, the cord generally falls backwards and the gas fills the anterior portion of the space (Fig 10) The explanation of this anterior position of the cord may be an abnormal local tension of the dentate ligaments which prevents the cord assuming a uniform posterior position BREIG has shown in cadavers that localized kyphosis may produce regional tension in these ligaments He has also suggested that the same effect may be caused by local protrusion or



Fig. 10. In the lateral view with vertical beam direction (left) the spinal cord is seen to lie anteriorly in the spinal canal. In the supine position lateral view obtained with horizontal beam (right) the spinal cord has fallen backwards revealing multiple disk protrusions.

herniation of a disk. One or several disk protrusions situated at the same level are commonly observed in gas myelograms when the examination is performed in the supine position. Another plausible explanation is that the dentate ligaments may not always permit free penetration of the gas so that a large amount collects behind them and produces tension. When the patient is examined supine the gas passes forwards and the cord moves backwards. This may be the reason for an anteriorly positioned cord in those cases in which neither kyphosis nor local disk protrusions exist.

SUMMARY

The sagittal dimensions of the cervical space and canal have been measured at gas myelography in a material of 85 patients. The appearances of the anterior and posterior aspects of the subarachnoid space as well as those of the dentate ligaments are described. The factors involved in the positioning of the spinal cord are discussed.



Fig 8 Appearance of the dentate ligament in lower thoracic region





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FROM THE DEPARTMENT OF DIAGNOSTIC RADIOLOGY (DIRECTOR PROF F KNUTSSON) UNIVERSITY HOSPITAL, UPPSALA, SWEDEN

ANASTOMOSES BETWEEN THE CORONARY AND BRONCHIAL ARTERIES

by

LARS BJORK

Enlargement of the bronchial arteries arising from the thoracic aorta or its branches that occurs in pulmonary atresia and severe pulmonary stenoses may provide all or a considerable part of the blood flow to the lungs Another pathway for the increased bronchial circulation is via collaterals from the coronary arteries to the bronchial arteries vessels that may be of considerable dimensions (Fig 1) and probably capable of depriving the myocardium of part of its blood supply It was considered of interest to investigate how often this collateral communication could be observed in cases with decreased pulmonary artery circulation

Material Sixty cases of Fallot s tetrad and 7 cases of pulmonary atresia were studied during the period 1952—1963 The age of the patients varied from 6 months to 32 years most of them were children under 5 years of age and only six were over 15

Method Angiocardiography with injection into the right ventricle was performed in all cases together with thoracic aortography in a few of the

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ZUSAMMENFASSUNG

An 85 Fällen wurde der Sagittaldurchmesser des Halswirbelkanals mittels Myelographie gemessen Das Röntgenbild des vorderen und hinteren Subarachnoidalraumes sowie des Ligamentum dentatum werden besprochen Die Faktoren die die Lage des Rückenmarkes bestimmen werden erörtert

RÉSUMÉ

L auteur a mesuré les dimensions sagittales de la moelle des espaces sous arachnoidiens et du canal rachidien cervicaux par myélographie gazeuse chez 85 sujets Il décrit les images des faces antérieure et postérieure de l espace sous arachnoidien et du ligament dentelé Il examine les facteurs qui influent sur la position de la moelle épinière

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Fig 3 Pulmonary atresia and VSD in a female infant aged 9 months RV angiocardiography Large collateral vessel from left coronary artery empties into a rete of bronchial arteries the finding was confirmed at autopsy

The existence of fine communications between the coronary arteries and the mediastinal structures has been shown in injection studies by e g HUDSON MORITZ & WEARN (1932) ROBERTSON (1930) CHRISTELLER (1917), and others have mentioned the possibility of a collateral circulation from the coronary to the bronchial arteries the only report on such a case seems however to be the one by VOSS (1856) who in a post mortem study of a male aged 37 with pulmonary atresia found a communication between the coronary arteries and the bronchial arteries ARVIDSON & MOBERG (1963) observed anastomoses between the bronchial arteries and the coronary arteries in cases of coronary arteriosclerosis in which the flow was directed from the bronchial arteries to the coronary arteries and the size of the collaterals was small

The frequency and size of the anastomoses between the coronary artery and the bronchial artery in the present material was striking The figure obtained in the cases of Fallot s tetrad is probably too low supplementary thoracic aortography would have produced better filling of the coronary arteries and probably demonstrated more anastomoses between the coronary



Fig. 1. Fallot's tetrad in a male aged 18 years. Thoracic aortography, lateral. A wide collateral vessel (white arrow) from the circumflex branch of the left coronary artery (black arrow) empties into a rete of bronchial arteries in the hilum of the lungs; poor filling of peripheral part of the circumflex branch; flow from coronary to bronchial arteries confirmed at operation and the collateral was ligated.



Fig. 2. Fallot's tetrad in a male aged 3½ years. RV angiocardiography, lateral projection. A tortuous collateral vessel (arrow) from the circumflex branch of the left coronary artery empties into a rete of bronchial arteries in the hilar region. The radiologic finding was confirmed at autopsy.

cases. Approximately 1 ml contrast medium per kg bodyweight was injected, and 12 or 6 films per second were obtained in lateral and a. p. projections with a biplane rollfilm changer. Good filling of both the right and the left ventricle and of the thoracic aorta was generally obtained.

Results and Discussion

Anastomoses between the coronary arteries and bronchial arteries were demonstrated by right ventricular angiocardiography in 6 out of 7 cases of pulmonary artery atresia, and in 5 out of 60 cases of Fallot's tetrad. There was definite evidence of flow from the coronary arteries to the bronchial arteries in all cases; in 4 cases the collateral artery was of the same size as the main circumflex branch of the left coronary artery (Figs 1, 2, 3) and in the remaining cases the collateral vessel was only moderate in size. The collateral always arose from the atrial branch of the circumflex branch of the left coronary artery; this vessel pursued a very tortuous course and was connected with a network of arteries in the hila of the lungs; this network of arteries was supplied also by the regular bronchial arteries.

FROM THE NEUROLOGY SECTION, VETERANS ADMINISTRATION CENTER, LOS ANGELES, CALIFORNIA, U S A

AUTO SUBTRACTION

A photographic technique for enhancement of detail in radiographic reproduction

by

W H OLDENDORF

The technique to be described offers a photographic method employing standard darkroom equipment for detail enhancement in radiographic reproduction. The procedure introduces only one step more than required to make a simple print of a roentgenogram. A projected out of focus negative image of the roentgenogram is used as a special light source for contact printing. Compared to previously reported similar methods it seems to be sufficiently simple and flexible to justify presentation.

Technique Essentially a contact print of the original roentgenogram is made on high contrast film. The basic procedure is outlined in Fig 1. The first step is to photograph the transilluminated roentgenogram on film processed to produce a gamma near one. The size of the film used is unimportant. We use a 4 × 5 plate (10 cm × 12.5 cm) but 35 mm film would be equally satisfactory.

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artery and the bronchial artery These communications were generally relatively small, and probably of no or little clinical significance However, in four of the cases the anastomoses carried a considerable flow and this must have deprived the myocardium of a fair amount of its blood supply, these subjects may have suffered from what might be called a 'bronchial artery steal syndrome' *The preoperative angiocardiographic diagnosis could be* important for it would permit the identification and ligation of anastomoses when surgical correction of the Fallot anomaly was performed (see Fig 1)

SUMMARY

Anastomoses between the coronary arteries and the bronchial arteries were demonstrated by angiocardiography in 12 out of 67 cases of Fallot s tetrad and pulmonary atresia They were of considerable dimensions in four cases

ZUSAMMENFASSUNG

Anastomosen zwischen den Coronararterien und den Bronchialarterien wurden in 12 von 67 Fallen von Fallotsche Tetrade und Atresie der Pulmonalarterie bei der Angiographie gefunden In vier Fallen waren diese von betrachtlicher Grosse

RÉSUMÉ

Dans 12 cas sur 67 cas de tétrade de Fallot et d atrésie pulmonarie l angiocardiographie a montré des anastomoses entre les artères coronaires et les artères bronchiques Elles étaient de dimensions considérables dans quatre cas

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Fi ? \ rmal chest fil n processed rout nely (a) and follow ng the application of the auto-subtraction technique (b)

position and magnification of the enlarger We have found white notebook reinforcements placed in clear areas in opposite corners of the original roentgenogram to be very useful The projected image of the hole in these reinforcements is centered on the reinforcement still adhering to the roentgenogram

The enlarger is then defocussed to a degree which will cause a point source of light in the focal plane to be projected to a diameter of 5 to 8 mm This spot or circle of confusion will vary somewhat with different roentgenograms For our general use 5 to 8 mm seems satisfactory

This defocussing process will alter the magnification of the projected image on the baseboard an amount depending whether the lens is moved above or below its focussed position Compensation must be introduced into the positioning of the enlarger to allow the defocussed image to be coincident in size with the roentgenogram

Superimposition of this out of focus image with the roentgenogram can be made easier if the enlarging lens is stopped down to obtain good registration and then opened for the exposure This latter maneuver will not alter the magnification The previously mentioned reference marks can be accurately positioned by this means

When the out-of focus image is in good registration with the roentgenogram the back edge of the latter is taped to the enlarger baseboard A piece of un

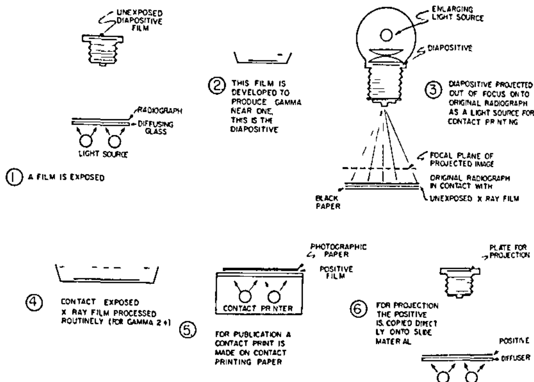


Fig 1 General plan of the auto subtraction technique

Empirically we have obtained better results if the film ASA rating is reduced to one half Thus we expose Dupont Commercial S film (rated at ASA 25) at an ASA rating of 12 averaging meter readings from several regions of the roentgenogram Dupont Commercial S film has been found to be suitable when developed for 2 minutes and 40 seconds in D 16 developer diluted 1 1 at 68° F Eastman Commercial film developed for 2 minutes in DK-50 diluted 1 1 would be equally suitable Actually any long tone scale emulsion would be useful if developed to achieve a gamma of one The film is dried after fixing and washing

This in focus negative is placed in an enlarger and projected onto the base board to form an image the size of the original roentgenogram The original film is positioned on the baseboard so that its detail and the detail of the projected negative image are fairly well superimposed Precise registration is unnecessary but the two images should be within 1 to 2 mm of each other in all regions

This image superimposition can be made easier if two opaque identification reference marks are made on opposite corners of the roentgenogram prior to the earlier exposure of the negative These marks can be used to adjust the



a b

Fig 3 Rout ne flat plate of the abdomen with ordinary printing (a) and following applicat on of the auto-subtraction technique (b)

auto dodging Although results comparable to electronic methods can be ob tained the method does not allow the extreme flexibility or range of cor rection for extremes of density in roentgenograms possible with electronic methods

It will be evident that the method proposed in this article represents a par ticular application of a masking technique that is well known to professional photographers This particular form has been described as unsharp masking such as described by YULE

What this technique does is to supply a special light source for equalizing the exposure for the contact printing of a roentgenogram In thin parts of the original roentgenogram the light source is reduced and in dense regions it is bright This allows all regions to fall within the useful range of the exposure curve of the high contrast material upon which the roentgenogram is contact printed If a negative were to be contact printed from the original roentgeno- gram onto high contrast material with a uniform light source few regions would fall within the useful exposure range and most of the reproduction would be over or underexposed It is this ability to print on high contrast material which makes any of the auto dodging techniques useful The automatic film

exposed radiographic film, the size of the original, is slipped under the original roentgenogram and a piece of clean glass placed over both films to obtain good contact A piece of black paper should be placed under the unexposed film to minimize back scatter from the baseboard

The exposure of the final coincident images is made Originally, test strips will be required, but after the technique is worked out for the particular enlarger and light source they can be run off quite rapidly These films can be run through an automatic processer as a routine film in the radiography department

This film will be a positive For projection purposes it can be copied directly onto slide material It can be contact printed or projected onto photographic paper to be submitted for publication

The total time required for the entire technique is about one hour for one film, but many films can be run as a group, thereby greatly reducing the average time per film We have found the exposure factors, once established, to remain quite constant from film to film

Discussion

In recent years considerable interest has been shown in electronic methods for enhancement of detail in radiographic films This has been most widely pursued for clinical radiography in the automatic dodging of radiographs, using a randomly moving large spot on a cathode ray screen as a light source, as described by Craig

The size of the circle of confusion of the projected out of focus image, in the photographic technique just described, is analogous to the size of the moving spot on the cathode ray tube The intensity of this moving spot is modulated through a feed back loop to bring about a general uniformity of exposure This allows the reproduction of the roentgen image onto another film of high contrast Largely because of the high contrast of this latter film, a considerable enhancement of detail in the original roentgenogram becomes possible

Such an electronic technique cannot, of course, reproduce detail not present in the original but can render such detail considerably more obvious A major practical outcome of this electronic technique has been in the preparation of roentgen images for publication or projection In these situations, subtle detail is often lost by the degradation of image quality inherent in the reproduction process The apparatus for electronically dodging radiographs is expensive and may be of such occasional use that its purchase may not be warranted in many instances

The photographic technique now described offers a simplified method for



Fig 3 Routine flat plate of the abdomen with ordinary printing (a) and following application of the auto-subtraction technique (b)

auto-dodging Although results comparable to electronic methods can be obtained the method does not allow the extreme flexibility or range of correction for extremes of density in roentgenograms possible with electronic methods

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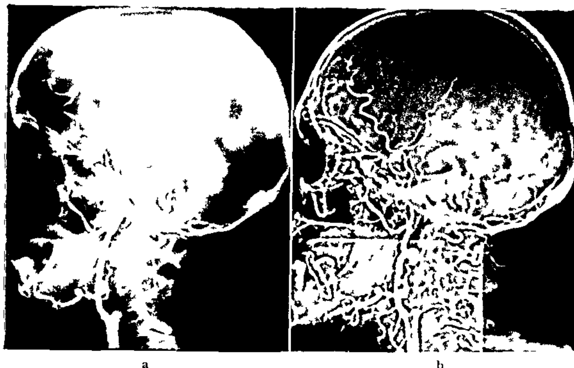


Fig. 4. Common carotid injection of 6 ml 50% diatrizoate into the common carotid artery with non-filling of the internal carotid artery processed routinely (a) and after the application of the auto-subtraction technique (b).

processer in our radiography department produces a gamma of 2 to 2.5 with commercial double emulsion roentgen film.

There is a relatively extensive European literature describing similar methods. Since the original paper of SPIEGLER & JURIS in 1930, there were reports by ZIEDSES DES PLANTES (1942), FRANTZELL (1950), and MATTSSON (1951), describing various techniques for generating an out of focus negative mask or diapositive for equalizing the exposure for all regions of the roentgenogram to obtain enhancement of detail.

All of these techniques other than that of FRANTZELL utilize contact prints of the roentgenogram, producing the out of focus image by a 3 to 5 mm separation of roentgenogram and diapositive during the contact printing. This creates two problems: (1) it requires the capability of processing for a gamma of one, a diapositive as large as the roentgenogram — with larger films such as chests and abdomens this would be costly and require special trays, solutions and drying facilities, (2) in obtaining defocussing by separation there occurs a radial scattering of light from the emulsion grains of the film nearest the light source, and this scatter is added onto the blurred image being produced as a

simple penumbra effect, the circle of confusion of the blurred image has, therefore, an indistinct edge and is ill defined.

The projection technique of FRANTZELL is the only description utilizing a miniature diapositive. In that technique, the diapositive is exposed out of focus, and subsequently projected back through the same lens, still out of focus. In effect, this doubles the circle of confusion of the diapositive image. The technique described in the present article differs in that the diapositive is exposed in focus and all of the defocussing is obtained in the subsequent enlargement. In FRANTZELL's technique a combination camera and enlarger was constructed with special attention to the capability of repositioning the developed diapositive to precisely the position it occupied when exposed.

Despite its marked similarity to FRANTZELL's approach, the present technique seems of interest. It has the advantage that a sharp reduced negative (diapositive) is retained for filing. It further allows complete control of the degree of defocussing and requires no modification of standard darkroom equipment.

If the full potential of any of these unsharp masking techniques is to be achieved, the diapositive should be, from a densitometric standpoint, as close to an inverse of the original roentgenogram as possible. A low contrast diapositive will create a lessened correction and a high contrast diapositive will over correct. The theoretical and practical problem in the making of precise diapositives using modern films and chemicals has been elaborated upon by ZIEDSES DES PLANTES (1961). Although a perfectly exposed and processed diapositive is desirable, quite good results can be achieved with a less than optimum diapositive.

The diapositive is as important in the present procedure as in the subtraction technique of ZIEDSES DES PLANTES since one may look upon these auto masking techniques as an auto subtraction. In this sense the regional non-discrete information is being subtracted from the roentgenogram while the sharp details remain and can be accentuated by high contrast reproduction. In this auto subtraction the roentgenogram is made to produce its own subtraction diapositive and no other reference film is required. All of these techniques can not, of course, subtract sharp unwanted detail as in the subtraction technique of ZIEDSES DES PLANTES (1935, 1961).

Since all of these techniques are useful and have been in the radiologic literature for over thirty years it is interesting to speculate about their lack of acceptance particularly in America. Awareness of the value of auto-dodging or auto-subtraction in the reproduction of roentgenograms was not widespread until an electronic device to accomplish this same end was invented and advertised. It may be assumed that the simple photographic methods have offered

no incentive to a recognition of their merits. There is no doubt, however, that electronic systems offer a flexibility and range of control that could not easily be achieved photographically.

Acknowledgements

The author wishes to acknowledge the technical assistance of John Palmer R.T. and the cooperation of the staffs of the Radiology and Medical Illustration Services of the Wadsworth Veterans Administration Hospital.

SUMMARY

An unsharp masking technique for enhancement of detail is described in which a contact print of the roentgenogram is made on radiographic or other high contrast film using the projected out of focus image of a small negative (diapositive) of the roentgenogram as a light source. The technique requires one step more than for making a simple print of a roentgenogram. Auto-subtraction is suggested as a term for this technique.

ZUSAMMENFASSUNG

Eine unscharfe Maskentechnik der Detailvergrosserung wird beschrieben, bei der auf einem röntgenphotographischen oder auf einem anderen kontrastreichen Film eine Kontaktkopie hergestellt wird, und zwar so, dass das projizierte unscharfe Bild eines kleinen Negativs (Diapositivs) der Röntgenaufnahme als Lichtquelle benutzt wird. Diese Technik macht einen Schritt mehr erforderlich als die Herstellung einer einfachen Kopie der Röntgenaufnahme verlangt. Für diese Technik wird die Fachbezeichnung Auto-subtraktion vorgeschlagen.

RÉSUMÉ

L'auteur décrit une technique de masque flou pour améliorer la visibilité des détails: on tire par contact sur film radiographique ou sur un autre film à grand contraste une épreuve de la radiographie en utilisant comme source de lumière l'image projetée floue (non au point) d'un petit négatif (diapositive) de la radiographie. Cette technique ne nécessite qu'une étape de plus que la simple reproduction d'une radiographie. L'auteur propose de l'appeler auto-soustraction.

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FROM THE ROENTGEN DEPARTMENT (DIRECTOR PROF ERIK LINDGREN), SERAFIMERLASARETTET STOCKHOLM

AN IMPROVED PHYSIOLOGIC CONTRAST MEDIUM FOR THE ALIMENTARY TRACT

by

G EMBRING and O MATTSSON

The barium contrast media commonly employed in studying the anatomy of the alimentary tract are generally also used for assessing the rate of gastric evacuation and the transit time through the small intestine despite the fact that they never produce any physiologic stimulus to the alimentary tract Addition of ordinary food to the contrast medium was practised at a very early stage in an endeavour to gain a better idea of the mode of gastric emptying and passage through the small intestine KOLTA & SCHOULTZ as early as 1931 added barium to well dispersed meat egg and fat and SANDSTROM & HALLBERG in 1946 used meat balls with mashed potatoes prepared with barium The interest in such physiologic investigations has increased in recent years especially in studies of the dumping syndrome

ABBOTT KRIEGER & LEVEY (1958) tried a barium meal containing a well dispersed mixture of bread and butter a boiled egg with a little salt, coffee and fruit juice and ABBOTT KRIEGER, LEVEY & BRADSHAW in 1960 used a protein product available for general use (Protenum) together with milk ice cream and sugar blended mechanically with barium sulphate The fol

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Good delineation of the muscosal folds was obtained with the method described.





lowing year, ABBOTT, KRIEGER & BRADSHAW (1961) tried a barium and chocolate milkshake. MADSEN & RASMUSSEN (1964) used another product on the market (Reducal) mixed with sugar and barium.

BORGSTRÖM et coll. (1957) suggested a liquid test meal consisting of protein, fat and carbohydrate for investigation of the digestion by the tube technique. As the digestive pattern of this test meal was well known, MATTSSON,

LAGERLOF & PERMAN (1959) and MATTSSON, PERMAN & LAGERLOF (1960) used it as their basis adding to it a stable barium sulphate suspension prepared according to the principles described by EMBRING (1956) and MATTSSON (1956), which imply the addition to the barium sulphate of certain water soluble neutral salts in very small amounts A standardized barium meal with physiologic properties was obtained and the aforementioned investigators used it to study the normal transit time, later (1961) they used it for the examination of patients with steatorrhea It was also used to study the transit time in the dumping syndrome (PERMAN & MATTSSON 1962) It proved possible to demonstrate typical differences in transit time between patients with steatorrhea or the dumping syndrome and normal subjects The same physiologic barium meal was used by HEDENSTEDT LILJEDAHL & MATTSSON (1961) in motility studies after partial gastrectomy In contrast to other physiologic radiopaque media the meal is homogeneous and hence offers possibilities for fairly accurate evaluation of the anatomy of the stomach and small intestine Since it provokes secretion in the stomach and intestine, it cannot however give such a clear anatomical delineation of the mucous membrane as the ordinary barium media

A disadvantage of this physiologic barium meal is that the liquid preparation when ready for use, cannot be kept for more than 2 to 3 days in a refrigerator It was therefore considered important to devise a physiologic barium medium capable of being stored in the same way as ordinary barium media and capable of being prepared for use as easily as the latter in other words a medium in powder form that contained barium sulphate protein fat and carbohydrate and could be mixed with water It is difficult when suitable roentgenologic density is required to mix ordinary barium sulphate with nutritive components without producing a highly viscous mixture However it was found that the addition of water soluble neutral salts which gave the barium sulphate a high suspension stability, also produced low viscosity of the mixture containing the nutritive components The writers used tri sodium citrate as the additional substance A fairly large amount of stable barium sulphate may be added to the nutritive components without the character of the meal being changed to any appreciable degree Protein and carbohydrate may be readily prepared as a water soluble powder It was more difficult to turn fat into powder form but this proved to be easier in the presence of the stable barium sulphate a well dispersed oil could thus be included in the mixture and an absolutely dry stable powder obtained This preparation is to be supplied in plastic bags containing enough for one examination and mixed with water will produce a solution ready for use within a few minutes Each bag of 218 g contains stabilized barium sulphate

Book reviews

Principles of Chest X ray Diagnosis By George Simon Second edition 207 pages and 200 illustrations Butterworth London 1962 Price 50 Sh

The blurb on the jacket of this book states that it has been written for the student radiologist and for the clinician who is particularly concerned with chest diseases whether he interprets the radiographs himself or has the cooperation of a radiologist The material is arranged under the descriptive headings of the X ray shadows instead of under the clinical disease labels The terms used are defined in the introduction in which it will be found that expressions such as reticulation, honeycomb shadows tubular shadows linear or band like shadows patchy cloudings companion shadows hairline shadows and ring shadows are considered acceptable With regard to reticulation it is stated that no pathological basis directly corresponds with this network which is the result of more or less linear shadows circular shadows and small ring shadows being superimposed on each other In the same incomprehensible spirit the term honeycomb shadows has been accepted instead of the other synonym mentioned namely cystic lung despite the fact *that the latter ought to give a much better idea* of the condition in question whether the examiner be a clinician or a radiologist Descriptive terms were often necessary in the days when little was known concerning the real conditions underlying the radiologic appearances but it surely ought to be one of the main tasks of every radiologist to translate the information provided by the films as adequately as possible into comprehensible morphologic and functional terms

The author attempts for instance to facilitate the differential diagnosis by roughly sorting out into groups all very small circular shadows (less than 2 mm in diameter) small circular shadows (greater than 2 mm to 2 cm in diameter) and large circular shadows (greater than 2 cm in diameter) This unbiologic attitude divorced from the more essential characteristics of the underlying condition is probably the main explanation for the new diagnostic confusion that the author introduces He himself appears to be aware of this when in a discussion on widely disseminated very small circular shadows in which a list of 83 different causes is presented he writes This formidable list of possibilities may at once be much reduced in an individual case by the clinical picture The logical consequence of this conclusion after the 83 different causes have been presented ought to be to utilize the possibility indicated for making a clinical division of the material and to describe within the new groups the radiographically demonstrable changes that may be of further assistance in the differential diagnosis The latter task is the most difficult but at the same time perhaps the most interesting side of diagnostic roentgenology and it should occupy a central position in the work of a radiologist

The author also touches upon the radiologic cardiac diagnosis Frankly erroneous statements such as that the heart is best measured by its transverse diameter ought not to occur in a text book The author s theoretical presentation of the heart and blood vessels would appear to be explained by the remarkable statement on page 123 that the indications for angiocardiography and the X ray appearances seen by this method are within the province of specialized cardiology and have therefore been omitted The reviewer is firmly convinced that modern radiologic cardiac diagnosis cannot be taught without the assistance of among other methods the specialized roentgen diagnostic method known as angiocardiography

It is evident from what has been said that this work does not fulfil modern requirements for a textbook of diagnostic radiology It is regretted that it cannot be recommended

Bjorn Nordenstrom

LUMBAR DISKOGRAPHY AND ITS CLINICAL EVALUATION By L Walk 135 pages 41 figures and 11 tables Bibliotheca Radiologica Fasc 3 S Karger Basel and New York 1962 Price 30 Sfr

Lumbar diskography is now being used routinely at some clinics to investigate pain states due to slipped disk This method of examination presents many problems and an incorrect technique may cause serious complications or give misleading information Hence a monograph aimed at giving according to the author all available experience and critically evaluating the possibilities and limitations of the method should arise considerable interest For those who are familiar with this field however the book provides little that is new and even contains several incorrect statements

An exhaustive and satisfactory survey of the older forms of puncture and injection is presented

The modern technique which in the reviewer s opinion is the form that should be used has not been mentioned however With this newer technique large amounts of contrast medium are injected without a local anaesthetic either in the medium or in the soft tissues of the back

With the old technique an incomplete pain reaction or none at all is obtained and the author has thus failed to make use of pain recordings which are of considerable significance to the final result of the examination In consequence he considers it difficult to distinguish old residual lesions from lesions causing symptoms and signs without applying myelography It would appear to the reviewer that there is no difficulty in detecting old residual lesions with a modern diskographic technique

The reader is given no information concerning how many cases in the material were operated upon or on the operative technique used Such data would naturally have been of great value for verifying the correctness of the author s conclusions

WALK maintains that rupture of a disk without root compression is unsuitable for surgical treatment He offers no evidence in support of this assertion however The explanation of his poor operative results in these forms of rupture may lie in an inadequate diskographic technique Other workers have reported good results in these ruptures

The classification and analysis of the illustrations are also open to criticism The expression early stage with partial rupture is often encountered but is not explained It would appear from Figs 5 and 6 as though no distinction had been made between these and normal conditions and this in turn means that an abnormally larger number of healthy lumbosacral disks have been included among the cases forming the material The occurrence of tissue sequester is taken as being synonymous with that of root compression in other investigations however the reverse has been reported

The bibliography referring to ruptures of lumbar disks and abdominal pain is not complete and the author appears to have disregarded the part played by diskogenic pain All publications dealing with the nervus sinu vertebralis and its relation to diskogenic referred pain have been omitted such authors as CLOWARD FERNSTROM HIRSCH STILLWELL, WIBERG and others ought to have been mentioned

The book in many places is difficult to read owing to the fact that the tables and explanatory texts are not printed in juxtaposition or because special terms are used before they have been explained in the text

Although it cannot serve as a handbook for beginners in this field the work is nevertheless interesting mainly because of the detailed review that is presented of the complications likely to arise in connection with lumbar diskography

Ulf Fernstrom

INTRAVENOUS CHOLANGIOGRAPHY By Robert I Wise 139 pages 116 illustrations and 2? tables Charles C Thomas Springfield, Ill, 1962

This monograph on cholegraphy is based on about 2 000 examinations performed by uniform method and it is obvious that the author has worked in collaboration with surgeons and pathologists and that each case has been studied in considerable detail the material has thus been well verified

It is not possible in a short review to mention all the interesting details that are included The exhaustive investigation into the relationship between contrast filling of the bile ducts on the one hand and the bilirubin and bromsulphalein values on the other, is a valuable contribution to our knowledge of the factors affecting the examination results

The author is to be praised for having stressed so clearly the fact that intravenous cholegraphy is a method mainly intended for the investigation of the bile ducts and that the gall bladder should in most cases be examined after the peroral administration of contrast medium It is also praiseworthy that the significance of tomography has been emphasized It is however somewhat surprising that the author prefers to use simultaneous tomography While the reviewer is fully aware of its advantages with respect to dosage conventional tomography would nevertheless appear to be preferable on the precept that only the best is good enough when such small differences in image contrast as may be obtained in cholegraphic examinations are in question

Particular attention has been paid to partial obstructions The author never uses morphine he considers that by avoiding this drug a diagnosis of partial obstruction may be made much more often than purely static appearances would justify The width of the ducts is regarded as being of limited significance only ducts wider than 15 mm are considered to enable an unequivocal diagnosis of obstruction to be made while exclusion of such a diagnosis would only be possible should the diameter be 5 mm or less The author introduces an interesting concept into the discussion on bile duct obstruction namely time density retention If the contrast density in the bile ducts two hours after the contrast injection is higher than at one hour this is taken as signifying partial obstruction This premise appears to be well documented and has provided the author s material with a considerable number of cases of obstruction which were later verified Contributions are advanced in support of the view that is becoming increasingly general namely that operation as such does not increase the width of the bile ducts

An interesting chapter is devoted to cystic duct remnants There is a remarkably high incidence of concretions in this part of the author s material Stress is however laid on the difficulties of making a roentgenologic diagnosis of such concretions as well as on the risks involved in the operative treatment of the remains of the intramural cystic duct At a time when post cholecystectomy symptoms are beginning to attract attention it would however seem to be important that this complex should be given more study

The book is marred by an unfortunate defect despite its undoubted merits although it was published in 1962 no literature later than 1959 has been included and this means that the author does not mention the modern views on the toxicity of contrast media With regard to cholegraphy for instance he says that the procedure may be carried out with the same freedom as intravenous pyelography Since the reviewer is familiar with the considerable differences in the circulatory effects of the modern contrast media used in cholegraphy and urography he is not able to share this opinion The author s negative attitude towards the possibility of obtaining adequate contrast filling of the bile ducts by peroral administration probably also reflects his failure to consider experiences reported during the last few years However these objections do not detract in any great measure from the book s value as an interesting contribution towards our knowledge of intravenous cholegraphy

Excellent illustrations have been obtained with the new polaroid procedure

Georg Fredrik Saltzman

ACTA RADIOLOGICA

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ROENTGENOLOGIC CHANGES IN POSTOPERATIVE, SEPTIC OSTEOARTHRITIS OF THE HIP JOINT

by

O BARTLEY and N CHIDEKEL

MICHELS KELLY & COZEN (1959) have described 16 cases in which post operative coxitis occurred after fracture of the hip joint *Staphylococcus aureus* was the organism responsible in 14 of the cases and *proteus* in two Luxation did not occur in this material and the roentgenologic diagnosis was not discussed A search of the literature has revealed no roentgenologic diagnoses in reports on postoperative coxitis

There are however many descriptions of hematogenic coxitis e g LAURELL 1927, BADGLEY et coll (1936) HEFKE & TURNER (1942) HARMON & ADAMS 1944, PILLMORE 1946) and JORUP & KJELLBERG (1948) The early roentgenologic changes in this disease as well as in coxitis serosa (DREY 1953) consist of a swelling of the soft tissue surrounding the hip joint and obliteration of the fatty contours in the intermuscular septa they were first described by LAURELL

The present report is concerned with the roentgenologic changes in post operative coxitis with particular reference to the early diagnosis the incidence of coxitis has however not been investigated Particular attention has been

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directed to the occurrence of pericapsular edema, decalcification with or without bone destruction, destruction of cartilage, luxation or subluxation and nail displacement.

Many layers of fatty tissue surround the hip joint and under ordinary conditions are readily apparent (Fig. 1). Two well defined fatty layers lie immediately above and lateral to the hip joint. According to DREY, the medial layer is situated between the gluteus minimus and medium muscles and the lateral layer between the gluteus medius and *maximus*. Another fatty layer exists below and medial to the hip joint, said to be situated medial to the iliopsoas. Finally, there is a fatty layer immediately medial to the obturatus internus. No soft tissue films were obtained in the present material which may explain why no changes in the obturatus internus muscle were noted. The fatty layers lateral to the hip joint are usually easy to define and were the only ones considered.



Fig. 1. Normal patient. Fatty layers lying closest to the hip joint lateral (←) and medial to the iliopsoas muscle (←→).

Material. The material consisted of 21 cases of postoperative coxitis and a control group. The latter comprised 42 cases with fracture of the femoral neck, in 30 of which osteosynthesis had been performed. The material was not selected in any way except that several roentgenologic examinations had been made after the injury and the fracture had healed without complication.

The coxitis material consisted of 21 patients, 14 women and 7 men, aged between 59 and 87 years. The general condition at the time of operation was often poor. Four patients had positive Wassermann reaction and 3 had earlier been operated for malignant tumour. One patient had undergone colostomy prior to osteosynthesis. Two patients already had sacral decubital sores before osteosynthesis, and one had a renal stone with a long history of urinary tract infection.

Sixteen of the patients had a fracture of the medial part of the femoral neck, four a fracture of the trochanteric region and one patient a fracture of the

femoral head with dorsal luxation Open reduction was performed in the last mentioned Only one osteosynthesis (by the Sven Johansson by the Aronsson, or the MacLaughlin method) or arthroplasty (Thompson Moore) was per formed in 12 patients while either several osteosyntheses or osteosynthesis followed by arthroplasty, were performed in the remaining 8 patients

Clinical picture All the patients were febrile for at least 2 weeks following the operation, thereafter most of them were subfebrile for the duration of the illness The sedimentation rate increased rapidly and usually reached a value of 100 mm/hour or more in connection with the operation it rose to no more than between 42 and 68 mm in 6 patients

Three of the eight reoperated patients presented this clinical picture after the first operation and in four it occurred following re operation Osteosyn thesis was performed first by the Sven Johansson method and 6 days later by the Aronsson method in one patient because of displacement of the nail The patient was febrile after the first operation but since the two operations were performed so close to each other and the roentgen films after the first were technically unsatisfactory the pericapsular soft tissues could not be judged It cannot therefore be stated from which operation the infection originated

A fistula occurred in the operation area in all but two of the patients from a few days to 8 1/2 months after the operation Bacteriologic cultivation of the fistular exudate was carried out in 14 of the 19 patients *Staphylococcus aureus* was isolated from 11 of these samples two of which also contained other bacteria such as *proteus* enterococci and pyocyaneus *Staphylococcus albus* was found in one sample and staphylococcus in another while the remaining sample contained *proteus*

Six of the patients have died to date with coxitis as a contributory cause

Roentgenologic findings

Control material No demonstrable pericapsular edema or any other changes were present at the initial or follow up examination

Coxitis material Pericapsular edema was never observed at the initial roent gen examination This change however appeared in all the cases after that oper ation from which the infection originated The two fatty layers lateral to the hip joint were no longer identifiable The pericapsular edema was already demon strable at the first postoperative examination when the films were suitable for analysis in 12 of the 21 patients it was observed within a month and in 3 within

directed to the occurrence of pericapsular edema, decalcification with or without bone destruction, destruction of cartilage, luxation or subluxation and nail displacement.

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The coxitis material consisted of 21 patients, 14 women and 7 men, aged between 59 and 87 years. The general condition at the time of operation was often poor. Four patients had positive Wassermann reaction and 3 had earlier been operated for malignant tumour. One patient had undergone colostomy prior to osteosynthesis. Two patients already had sacral decubital sores before osteosynthesis, and one had a renal stone with a long history of urinary tract infection.

Sixteen of the patients had a fracture of the medial part of the femoral neck, four a fracture of the trochanteric region and one patient a fracture of the



Fig. 3. Coxitis after osteosynthesis of a pertrochanteric fracture before operation (a) and ten months later (b). Marked decalcification and destruction of the acetabulum (c). After a further 9 months. The changes have progressed further; the upper lateral part of the acetabulum has been destroyed and the femoral head displaced; the fatty layers around the joint are ill defined.



a b

Fig. 2. Coxitis after osteosynthesis for fracture of the medial part of the femoral neck before operation (a) and 8 days after (b). The fatty layer lateral to the joint is visible in the former but obscure in the latter.

3 days following the operation. Seven of the patients presented no evidence of other roentgenologic changes when the pericapsular edema was first noted. Other changes never preceded the latter; the average time for the appearance of pericapsular edema was 1 1/2 months after operation and it persisted in all the patients during the entire investigation period.

Decalcification occurred in all patients either with or without demonstrable bone destruction of the joint surfaces and was observed first in the acetabulum. Recognition of the early minor changes was simplified when serial films were available for study. *The decalcification appeared before destruction of the joint cartilage in 8 patients and in none did the reverse occur.* Subluxation was however observed in one patient before decalcification. The average time for evidence of decalcification to appear was 2 1/2 months.

Destruction of cartilage occurred in all patients who could be assessed. Undefined were those in whom Judet's plastic prosthesis had been employed or in whom luxation occurred after an examination in which cartilage

the femoral head and the acetabulum was evident about 3 weeks after the onset of infection, the space then diminished considerably in conjunction with marked destruction of the joint cartilage, no luxation occurred

Subluxation was apparent before luxation in four of the 11 patients In one of these the distance between the femoral head and the acetabulum increased considerably and was first evident about 2 1/2 months after the infection the femoral head was displaced after 6 months In eight of the 11 patients the luxation occurred outwards forwards and upwards while in two patients the femoral head was displaced upwards through the acetabulum and in one the luxation was central Subluxation occurred on the average 4 months after the onset of infection while luxation was evident after about 6 months Subluxation was noted before decalcification in one patient, while in all the others subluxation or luxation were the last roentgenologic changes to be observed

Nail displacement The infection occurred in connection with osteosynthesis in seventeen of the 21 patients in eleven of these the operation was performed by the Johansson method in four by the McLaughlin method and in one by the Aronsson method, and in one finally by the Johansson method followed at an interval of 6 days by the Aronsson method In eight of the 11 patients in whom the osteosynthesis was performed by the Johansson method the nail slipped laterally 3 days to 4 months after the operation or on the average about one month from the onset of infection No displacement of the nail occurred in the remaining three patients

The point of the nail worked up to or perforated the femoral head surface between 1 and 6 months after operation in all the four instances in which osteosynthesis was performed by the McLaughlin method The nail was not displaced in the patient treated by the Aronsson method The Johansson nail had slipped out after 5 days and the point of the Aronsson nail had penetrated the femoral head 2 1/2 months after the operation in the patient in whom the osteosyntheses were performed at close intervals An alteration of the position of the nail thus occurred in 13 of the 17 patients When nail displacement took place following osteosynthesis by the Johansson method the nail slipped laterally but when the nail was fixed to the trochanteric part of the femur the point of the nail penetrated up to or through the femoral head surface

Discussion

A raised temperature for some time after operation on the hip joint followed by a long term subfebrile state combined with a rapidly increasing sedimenta



Fig 4 Coxitis after osteosynthesis for fracture of the medial portion of the femoral neck four months after operation Obliteration of the fatty layers and decalcification of bone around the joint with marked cartilage and bone destruction luxation of the femoral head centrally with new bone formation medial to the joint

destruction had not been present The destruction occurred very early in some patients (within a month in 4 patients) although it was generally revealed later The change was demonstrable on the average 3 1/2 months after the onset of infection

Luxation or subluxation could not be assessed in 2 of the 21 patients A Judet prosthesis was employed 4 1/2 months after the onset of infection in one of these, up to that time neither subluxation nor luxation had occurred The artificial joint head became somewhat displaced 2 days after the operation and luxation occurred a month later It was not possible to relate the luxation of the artificial head to the infection In the other patient the infection arose in connection with removal of the Judet prosthesis

The femoral head was not displaced in 4 patients, in two of these the observation period was short being only about 3 months, in the other two it was over a year

Subluxation occurred in 4 and luxation in 11 of the remaining 15 patients The femoral head was displaced outwards, forwards, and upwards in 3 of the 4 patients with subluxation In the fourth an increased distance between

relation to coxitis and might thus be considered an indication of the latter The roentgenologic changes including the possible occurrence of pericapsular edema, concomitant with necrosis of the femoral head and nail displacement not related to coxitis will be more closely examined in further communications

Decalcification of parts of the hip joint always began in the acetabulum and except for nail displacement was the second earliest roentgenologic change to indicate coxitis The frequency of subluxation or luxation was high in the present material It is noteworthy that MICHELS et coll failed to find this alteration in any of their 16 patients the reason for which is obscure Luxation occurred despite bed care in the majority of the patients of the present material A contributory factor to the occurrence of luxation in the material was destruction of the upper lateral part of the acetabulum which appeared before the luxation Subluxation was evidenced by an increased distance between the femoral head and the acetabulum in two patients The cause of this change could have been either an extravasation into the joint or the abundant proliferation of granulation tissue in the joint such tissue was observed at two autopsies

SUMMARY

The roentgenologic changes in postoperative coxitis in 21 patients are described Pericapsular edema was the first change to be observed and was sometimes present as early as a few days after the onset of infection It was not found in a control group of 42 uncomplicated femoral neck fractures

ZUSAMMENFASSUNG

Das Rontgenbild der postoperativen Coxitis wird in 21 Fallen beschrieben Perikapsulares Oedem war das erste sichtbare Zeichen und konnte manchmal schon einige Tage nach Auftreten der Infektion beobachtet werden Dieses Zeichen fehlte in einem Vergleichsmaterial von 42 Fallen von Schenkelhalsbruchen ohne Komplikation

RÉSUMÉ

Les auteurs décrivent les signes radiologiques de l arthrite coxo-femorale post-opératoire chez 21 malades L œdeme péricapsulaire est le premier signe observable et existait parfois des les premiers jours suivant le debut de l infection Ce signe n existait pas dans une serie temoin de 42 fractures du col fémoral non compliquées

tion rate, indicate that infection has occurred Further support for this assumption is the high frequency of postoperative fistulae *Staphylococcus aureus* was the organism most often found in the fistula exudate in the present material This confirms the previous findings of MICHELS et coll

The complication of postoperative coxitis carries a high mortality rate Early diagnosis should improve the prognosis, and the condition must not be mistaken for other more common infections, e g pneumonia or urinary tract infection

The roentgenologic appearances in postoperative coxitis are characteristic, they always included pericapsular edema and decalcification Destruction of cartilage, luxation or subluxation and displacement of the nail often occurred concomitantly The average time for the first roentgenologic change to appear was shortest for the pericapsular edema and longest for the subluxation or luxation The time of the demonstration of changes must naturally depend upon the interval between the roentgenologic examinations When the intervals were short and the patient was investigated in close relation to the operation, the pericapsular edema was noted generally within 1 month and in three patients as early as after 3 days

The fact that additional changes were usually simultaneously demonstrable means either that the skeletal alterations occurred very quickly or that the patients were examined at too great time intervals, probably the latter The pericapsular edema always persisted during the investigation period and was never present at the time of the first preoperative examination The change thus comprises, particularly when considered in the light of its absence in the control material, a roentgenologic early indication of coxitis Patients with a temperature of unknown origin, after an operation upon the hip joint should therefore be subjected to repeated roentgen examinations as early as possible If pericapsular edema is evident, but no fistula is present, a confident diagnosis of coxitis may be obtained by puncture of the joint and cultivation of the synovial fluid

Complications other than coxitis such as displacement of the nail and necrosis of the femoral head, may occur after osteosynthesis The frequency of nail displacement in the present material of postoperative coxitis was very high (76 %), in comparison with those reported by LINTON (1944) and ODEN (1946) in cases without coxitis Nail displacement occurred in 25 (19 %) in the first material consisting of 134 patients in the majority of whom osteosynthesis had been performed by the Sven Johansson method ODEN had 146 patients all treated by the same method, in 64 of whom (44 %) nail displacement was noted A comparison of these materials shows that nail displacement occurred at a (statistically significant) higher frequency in

FROM THE SURGICAL ROENTGENDIAGNOSTIC DEPARTMENT (DIRECTOR DOCENT ROLF KOHLER), UNIVERSITY CENTRAL HOSPITAL, HELSINKI FINLAND

PYELO URETERITIS CYSTICA

Report of a case

by

ROLF KOHLER

Pyelo ureteritis cystica is characterised by cyst like formations in the wall of the renal pelvis or ureter usually associated with an inflammatory condition of the upper urinary tract Some hundred cases have been reported in the literature although a great number of them have been incompletely described The diagnosis is nowadays usually established roentgenologically

The first description of ureteritis cystica was recorded by MORGAGNI in 1761 One of his two autopsy cases had had chronic urinary obstruction and proximally both ureters contained spherical drops of various sizes They did not admit of *being wiped away with the sponge, but by compressing them between finger and scalpel they were reduced to a viscid water tinged with a faint colour of tobacco*

The first cases diagnosed by pyelography were described in 1929 by JACOBY and by JOELSON KNUTSSON (1935) reported the first two cases of ureteritis cystica from Scandinavia ORNING (1941) described urographic findings of cystic formations in a renal pelvis and ureter and the bladder in a man aged 63 while SKOG

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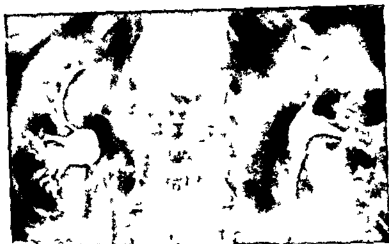
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PILLMORE G U Clinical radiology Davis Philadelphia 1946



a



b

Fig 1 Ur graph a) Fai t fill g def cts cranially and caudally n the right r nal pel i Num rou harply demarcated ound d defects n the left pelv s and u te I p lla ne oses b laterally n both upper poles Pyelo-u eterit s c st ca I Three ea I t Urograph c appearances unchanged

STAD (1949) diagnosed pyelo ureteritis cystica in a woman of 48. Of the larger collected materials, mention may be made of that by McNULTY (1957) who analysed 16 cases, which he considered to be reliably verified from among the original 31 and to which he added 3 cases of his own. LOITMAN & CHIAT (1957) reported, surprisingly enough, 25 cases of their own from a New York clinic. Over 90 cases were found by VILCA PIRES (1959) in the literature (exclusive of the 25 mentioned above) but this author considered that only 34 of them were fully described.

The aetiology of the disease is unknown, but it is held with almost complete unanimity that the cysts are formed secondarily to chronic inflammation. The coliform bacillus is the commonest causative organism, but cyst formations have been encountered in connection with bilharziasis, pentastomiasis, Protozoa infections, etc. It has also been suggested that concrements that lodge for a long time in the urinary tract may be conducive to cyst formation.

Opinions differ regarding the mechanism of development of the condition. The theory advanced by VON BRUNN (1893) has won the most support. He believed that under the stimulus of chronic inflammation downward proliferation of the surface epithelial cells takes place, and that these cells become cut off from the surface by ingrowing fibrous tissue and undergo degeneration to form cysts, which later migrate to the surface. A careful microscopic examination was made by BOTHE & CRISTOL (1942) of 54 pairs of ureters and they established facts that supported VON BRUNN's theory. The theory of the genesis of this disease advanced by STIRLING & ASH (1941) however also has its advocates.

The condition occurs in the older age groups and is slightly more common in women. There are no pathognomonic signs and the patients mostly display the usual signs of chronic urinary tract inflammation. Haematuria is strikingly common and has been assumed to be caused by rupture of the cysts. Pain is often due to calculi, but constriction or blocking of the ureteral lumen by the cysts may also be a cause.

Case report

Woman, aged 75, previously healthy, with a raised temperature and complaining of pain in the right lumbar region; in addition she had frequent and painful micturition but no haematuria. The patient's condition improved under medication but pain in the back persisted and she was admitted to hospital 2 months after the first onset of symptoms. The urine contained profuse Gram-negative bacilli and the patient was intermittently subfebrile. Urography revealed isolated filling defects in the right renal pelvis and numerous sharply demarcated filling defects in the left renal pelvis and ureter. There were also papillary necroses in both upper renal poles (Fig. 1a). Pyelography demonstrated the changes in the ureters extremely well (Fig. 2); on the right side the nodules were relatively sparsely distributed, but on the left they had run together into larger continuous formations of honeycomb appearance. The bladder on cystoscopy was normal. The urine became sterile after three weeks' treatment with antibiotics but the renal function had deteriorated.

addition elongated and larger as HEUCK (1949) pointed out Non opaque calculi are usually solitary and should not cause any particular difficulty in the differential diagnosis A tuberculous granuloma is also considered capable of causing defects suggesting pyelo ureteritis cystica but is accompanied by other signs of urogenital tuberculosis and should therefore be easy to identify It has not proved possible universally to verify from cases observed later the view propounded by HINMAN JOHNSON & McCORKLE (1936) that 'dilatation of the ends of the major calyces with narrowing of the arms of the calyx below and cystic dilatation at the ureteropelvic junction is typical of cystic pyelitis The changes described will be found in all kinds of cases of urinary infection

No reliable therapeutic method has been described so far Treatment for infection appears to have no effect on the cysts It has been suggested that the cysts may heal through spontaneous rupture and disappear, but there are no reports of systematically controlled cases The case now reported was probably followed up for the longest period (6 1/2 years) KINDALL (1933) treated his case with ureteral catheterization and irrigation with 2 per cent silver nitrate and reported that the number of cysts was considerably reduced This method has been experimented with e g by KOPP (1946) with good results Introduction of a catheter may cause rupture of the cysts and may be regarded as a therapeutic measure although a word of warning is appropriate The present case, which was catheterised twice developed oliguria and elevated non protein nitrogen Impaired outflow in consequence of ureteral irritation is considered to be the principal cause of this complication Operation is probably necessary only in the presence of complicating calculi or in the event of loss of function (e g McNULTY VEIGA PIRES)

SUMMARY

A case of bilateral pyelo-ureteritis cystica in which the appearances remained unaltered over a control period of six and a half years is reported The clinical radiologic and histologic features are reviewed and the differential diagnosis is considered

ZUSAMMENFASSUNG

Ein Fall von beiderseitiger Pyelo-ureteritis cystica in dem das Röntgenbild über eine Zeitspanne von 6 1/2 Jahren unverändert blieb wird beschrieben Die klinischen röntgenologischen und histologischen Erscheinungen sowie die Differentialdiagnose werden im Einzelnen erörtert

RÉSUMÉ

Présentation d un cas de pyélo-urétérite cystique bilatérale dont l aspect radiologique est resté inchangé pendant une période d observation de six ans et demi L auteur en rapelle les signes cliniques radiologiques et histologiques et en étudie le diagnostic différentiel

The patient subsequently had intermittent bouts of urinary infection but the urographic appearances were unchanged 3 years later (Fig 1b) Six and a half years later when the patient was 81 she still complained of symptoms of urinary tract infection and had to be re admitted to hospital The renal function was then considerably reduced and the previous bilateral filling defects were identified only with difficulty



Fig 2 Pyelography The whole of the left ureter is involved

Discussion

The diagnosis of pyelo ureteritis cystica has been established clinically by pyelography in a surprising number of the published cases although urography is by far the more common urologic contrast medium method Reduced renal function on account of chronic infection or stasis is probably the explanation for this Urography would appear to the author to be the most suitable diagnostic method provided the excretion capacity of the kidney is unimpaired Ureteral compression should be used, as pointed out by VEIGA PIRES this routine, which should include films without compression at the beginning and end of the examination, is probably the best procedure Pyelography may be valuable for special studies in which gradual contrast filling is necessary (KNUTSSON) The lower half of the ureters is obviously the section in which the pyelographic examination technique is primarily indicated

In the differential diagnosis of pyelo ureteritis cystica it is necessary to exclude all changes that may produce small, rounded filling defects These may be caused e g by air bubbles in the form of artefacts at pyelography, by gas forming microbes, or in connection with fermentation of sugar in the urine of diabetics Gas bubbles are highly mobile and therefore easy to exclude It is more difficult to distinguish papillomas and polyps from cystic formations MCNULTY pointed out that most multiple papillomas are situated in the lower part of the ureter, whereas cysts are more common higher up This was not accepted by VEIGA PIRES It should be possible, however to distinguish papillomas from cysts because the former are less sharply demarcated and, in

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EFFECTS OF IODIPAMIDE ON THE KIDNEYS

by

P LINDGREN, H NORDENSTAM and G F SALTZMAN

Iodipamide (Biligrafin Cholografin) is one of the parenterally administered contrast media in daily use which may produce fairly severe side effects The reactions observed clinically are too well known to need recapitulation in the present connection Both clinical (SALTZMAN & SUNDSTROM) and experimental (LINDGREN & SALTZMAN LINDGREN et coll) studies have been carried out to ascertain the effect of the intravenous injection of iodipamide on the blood flow The most striking reaction is a fall in the blood pressure immediately after the injection

As the kidneys have often proved to be highly sensitive to contrast media especially to the di iodized substances used earlier and to the acetrizoate preparations it was thought that a study of the effect of iodipamide on the kidney might yield information of interest The investigation was mainly concerned with the blood flow and histologic changes The circulatory effects of iodipamide preparations somewhat resemble those evident after sodium acetrizoate injections (LINDGREN & SALTZMAN) both substances producing a marked fall in blood pressure

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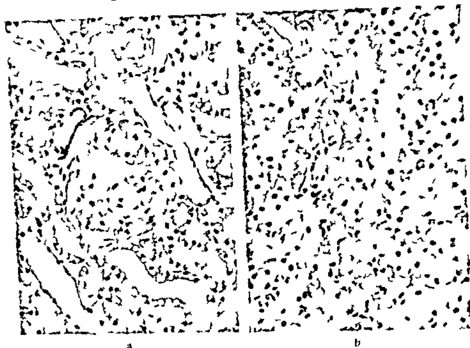


Fig 2 Cortex (a) and medulla (b) from kidney of cat after injection of iodipamide into renal artery Vessels dilated and filled with tightly packed blood cells reduced stainability of the nuclei in the endothelium of the glomeruli the swollen glomerulus completely fills out Bowman's capsule Oedema Haematoxylin eosin × 240

tense and enlarged A comparative study with the injection of a diatrizoate preparation produced little or no effects demonstrable with the technique used

Although iodipamide is never injected intra arterially in clinical work we considered that a study of the effect produced by this substance when injected into the renal artery would be of some theoretical interest if it should prove possible to compare this medium with the preparations used by LINDGREN The effects were investigated in cats the experiments being conducted in the same way as by LINDGREN

The left kidney was exposed retroperitoneally via an incision in the flank immediately below the ribs The blood flow was measured by a drop chamber technique that has been described elsewhere (LINDGREN) The blood pressure was measured in the carotid artery and together with the blood flow was recorded with a Grass Model 5 Polygraph

Biligrafin forte (methylglucamine iodipamide) in a 50 % solution was the contrast medium used in all the experiments In two cats, it was injected in



Fig. 1. Cortex (a) and medulla (b) from kidney of cat not given contrast medium. Haematoxylineosin × 240.

The observation of LINDGREN et coll. that iodipamide causes increased intravascular aggregation of the erythrocytes is another reason why the renal blood flow has received attention in connection with parenterally administered contrast media. It would seem logical to suppose that in addition to its effect on the pulmonary blood flow erythrocyte aggregation might also have some influence on the renal flow.

Experimental investigations

Intra arterial administration. The circulatory effects of a contrast medium on a limited vascular area, i.e. the direct vascular effect, may be best studied by examining the blood flow after an intra arterial injection (LINDGREN & TORNELL). The effect produced by intra arterially injected acetrizoate and diatrizoate preparations on the renal blood flow has been investigated by LINDGREN. He found that contrary to what had been observed in other vessel areas the flow in this region decreased even after the injection of very small amounts of sodium acetrizoate. When the dose was progressively increased the blood stream gradually came to a standstill and the kidneys became cyanotic,

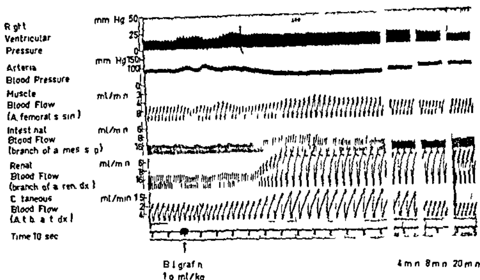


Fig 4 Intravenous injection of iodipamide (1 0 ml/kg) Fall in peripheral blood pressure, pressure increase in the pulmonary artery and decreased blood flow in various tissues The decrease in renal flow persisted long after the other effect has disappeared

media such as sodium diatrizoate did not give rise to appreciable changes in the blood flow

We have studied the renal blood flow in 10 cats after rapid intravenous injection of iodipamide The blood pressure and the renal flow were measured in the same way as indicated above for intra arterial administration

The measurements of the renal blood flow were in a few cats supplemented with concurrent recordings of the circulation in other organs (Fig 4) A dose of 0 53 to 1 ml/kg bodyweight of the contrast medium was given by rapid injection The dosage was thus high but it was not in excess of a corresponding double dose of Biligrafin forte in a small patient A transient decrease in the renal flow recordable only while the fall in blood pressure lasted was noted in 8 of the 10 cats (Fig 3) and it would seem reasonable to assume that the decreased flow in these animals was a direct result of the fall in pressure A marked divergence from this type of reaction was however observed in two instances These two cats reacted with a decrease in the renal flow which admittedly was reversible in at least one of the animals but which lasted much longer than the decreased blood pressure and thus could not be explained solely as a result of the pressure fall (Fig 4) The reaction in these two animals thus resembles that obtained after an intra arterial injection Both animals had received a dose of 1 ml/kg

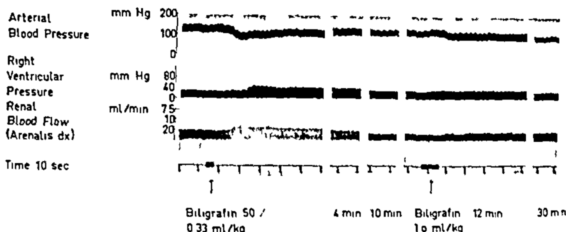


Fig. 3. Effect of two intravenous injections of iodipamide. The first injection caused a fall in peripheral blood pressure, elevated pressure in pulmonary artery and decreased renal blood flow; all these effects subsided simultaneously. The second injection produced only insignificant effects although the dose was 3 times larger.

progressively increased doses, starting with 0.05 ml/kg bodyweight. Even the smallest doses caused an appreciable decrease in the flow, and the stream ceased almost completely after the animal had received a total dose of 1 to 2 ml/kg. The kidneys were removed at a stage when the flow had decreased to a minimum; they were found to have the same gross appearances as the kidneys examined by LINDGREN after repeated intra-arterial injections of sodium acetrizoate, in other words they showed cyanotic discoloration, they were large, and the capsule was tense.

The renal capillaries histologically were greatly dilated and filled with closely packed red blood cells. The endothelium in the capillaries of the glomeruli was swollen and its stainability was reduced, indicating devitalization. The swollen glomeruli filled out the Bowman's capsules completely. Both cortex and medulla were markedly oedematous, but there were no signs of interstitial haemorrhage (Fig. 2, cf. Fig. 1).

Intravenous administration. Few investigations have been carried out to ascertain the effect on the blood flow of intravenous injections of contrast medium. The fall in blood pressure that takes place after clinical doses of iodipamide is well known, but such a fall has also been reported after large doses of less toxic contrast media, such as those of the diatrizoate type (READ, BERNSTEIN & EVANS, and others). LINDGREN & SALTZMAN made a study of the blood pressure and the peripheral blood flow after intravenous injection of contrast media, and noted a transient decrease in the flow after iodipamide injections in connection with measurements of muscle blood flow. This decrease ran parallel with a fall in blood pressure and had probably been caused by it. Other contrast



Fig 6 Cortex (a) and medulla (b) from cat kidney 15 min after slow intravenous injection of iodipamide (1 0 ml/kg) No pathologic changes Haematoxylin-eosin × 240

Roentgenologic investigations in man

In the light of the findings from the animal experiments the cholegraphy material at Serafimerlasarettet was studied to ascertain whether any changes in renal size had occurred during the examination All the patients irrespective of weight had received a routine intravenous injection of 20 ml Biligrafin forte As the measurements were made in roentgenograms that were already in existence and were from examinations that had not mainly been concentrated upon the kidneys it is obvious that exact determination of volume was not possible We confined ourselves to measuring the length of the right kidney before the Biligrafin injection and during the hour immediately following it In order to preclude the possibility of subjective selection the films were first judged from the standpoints of the comparability of the projections and the measurability of the kidneys those proving suitable from these aspects being used for the measurements

Because of lack of knowledge regarding tachyphylaxis after consecutive doses of Biligrafin and which applies both to falls in blood pressure and to



Fig 5 Cortex (a) and medulla (b) from a cat kidney 15 min after rapid intravenous injection of iodipamide (1 0 ml/kg) Marked oedema dilatation of Bowman's capsules and the tubules Haematoxylin eosin × 240

Histologic studies were carried out on 6 kidneys from cats that had received an intravenous dose of 1 ml Biligrafin forte per kg bodyweight The kidneys were removed 15 minutes after the contrast medium had been injected The microscopic appearances were the same in all the cases and fairly severe oedema of both medulla and cortex was present The Bowman's capsules and the tubules were markedly dilated The difference between the renal parenchyma of healthy non injected cats and that of the animals given Biligrafin forte intravenously was striking (Figs 1 and 5) None of the other changes observed in the kidneys after injection of contrast medium into the renal artery was evident after intravenous injection

Biligrafin forte in a dose of 1 ml/kg was in a few cats injected slowly, no change at all in the renal blood flow, and only a slight fall in the blood pressure, could be observed in these animals Histologic study of the kidneys from 3 cats after slow intravenous injection (5 min) of iodipamide in a dose of 1 ml/kg revealed no changes (Fig 6) For comparison, the kidneys from 3 cats given a corresponding intravenous dose of a diatrizoate preparation (Urografin 60 %) were examined histologically these kidneys also presented no changes

rapid injection we have no possibility of obtaining a suitable material for comparison A renal enlargement of 14 % and 8 %, respectively was noted in two cases in which injection had been given rapidly In the ten cases in which the medium had been injected slowly changes in kidney size were infinitesimal or absent

Discussion

Iodipamide appears to have largely the same effect on the kidneys as the acetrizoate preparations The similarities between the circulatory effects of intra arterially injected acetrizoate (LINDGREN) and those of iodipamide are striking These two groups of contrast media also appear to produce the same morphologic changes Both the macroscopic (LINDGREN) and the histologic changes (BERG et coll) observed after the intra arterial administration of acetrizoate and intra arterial diatrizoate preparations (EDLING et coll) bear a strong resemblance to those observed by us after the injection of iodipamide into the renal artery

Intravenous injections of iodipamide also seem capable of causing disturbance in the renal blood flow as well as histologically demonstrable lesions in the renal parenchyma Whether these changes may lead to permanent kidney damage is not clear Judging by the clinical evidence however it seems unlikely that any appreciable damage arises

The findings in connection with rapid injections of iodipamide as well as the difference noted between the effects after rapid and after slow injections respectively once more bring into the limelight the question of the significance of the injection rate There would seem to be no justification for exposing patients to the risks involved in rapid injections A word of warning might again be raised against the use of iodipamide when an oral contrast medium will give equally good information We cannot as yet abandon iodipamide but the indications for its use should be narrowed This medium should be used only for examination of the bile ducts and even then due consideration should be paid to the state of the patient s cardiovascular system

SUMMARY

The renal blood flow was studied experimentally in 10 cats after intra arterial and intravenous administration of iodipamide Six of the kidneys were examined histologically The relationship between the effects observed and the injection rate is considered The kidney size was measured in a clinical material after rapid and slow injections of this contrast medium The significance of the findings for the continuation of the use of iodipamide in roentgen diagnosis is discussed

Table

Influence on length of right kidney after injection of Biligrafin in total of 50 cases — The changes in the 0—4 mm group are regarded as not significant and as lying within the range of measurement error

	Increase in length in number of cases		
	10 (+) mm	5 to 9 mm	0 to 4 mm
Rapid injection	13 (26 %)	16 (32 %)	21 (42 %)*
Slow injection	0 (0 %)	1 (2 %)	49 (98 %)**

* Two cases with a decrease of 1 mm in kidney length are also included

** Thirteen cases with a decrease of 1 to 3 mm in kidney length are included

other effects, Biligrafin forte was during the years 1958 and 1959 administered by rapid injection (20 ml within 15 to 30 sec), this principle was applied because an earlier investigation, with first a slow injection of the medium and then, 45 min later, a rapid injection, had shown that the latter produced no more frequent or stronger side reactions than the slow one (SALTZMAN) Since 1961, when it became obvious that this result could be ascribed to tachyphylaxis and that rapid injection leads, in fact, to increased side effects (SALTZMAN & SUNDSTROM), Biligrafin has been given by slow injection (about 5 min)

Fifty cholegraphies from the rapid injection period, which fulfilled the aforementioned requirements, were studied in succession, and the changes in length of the right kidney are recorded in a Table It would seem as if a considerable number of patients develop renal swelling after rapid injection of 20 ml Biligrafin forte It was often possible to measure the kidney in question in several films obtained within the first hour after injection and it appeared from these that renal enlargement may arise even as early as during the first 15 minutes and then persist practically unchanged for the first hour after injection It should however be stressed that the writers have no information concerning any clinically demonstrable kidney damage in these cases

An equally large series of cholegraphies from the slow injection period was selected in accordance with the same principles as in the preceding material The measurements on the right kidney are also given in the Table It emerges from this study that a slow injection of Biligrafin apparently has little or no effect on the renal size

It may be mentioned that attempts were also made to achieve a more exact assessment of the kidney size by MOELL's method The material examined, 12 cases, is however too small to allow definite conclusions to be drawn As in recent years we have not considered it advisable to administer Biligrafin by

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XANTHOGRANULOMATOUS PYELONEPHRITIS

A case report with angiographic findings

by

JOSHUA A BECKER

Xanthogranulomatous pyelonephritis is a form of severe chronic inflammation of the kidney This disease entity was first described by SCHLAGENHAUFER in 1916 and since this initial description a small number of case reports have thrown light on the clinical and pathological features (1 2 4 6 7 8 9 12) Recently we performed nephroangiography when examining a patient with xanthogranulomatous pyelonephritis of the right kidney This is the first report to our knowledge of an angiographic examination in this disease

Case report

The patient was a 34 year-old negress with a history of recurrent urinary tract infections for 7 years At a urographic examination in 1962 there was no secretion on the right side Cystoscopy performed one year prior to admission to the hospital showed elevation of the trigone and a narrow right ureteric orifice Bilateral retrograde urography was attempted but only the left ureter was catheterized The physical examination on admission revealed a tender mass in the right flank

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ZUSAMMENFASSUNG

Blutdurchströmung der Niere wurde an 10 Katzen experimentell studiert nachdem man Iodipamid intra-arteriell oder intravenös gegeben hatte. Sechs dieser Nieren wurden histologisch untersucht. Der Grad der histologischen Veränderungen wurde mit der Injektionsgeschwindigkeit in Bezug gebracht. An klinischem Material wurde die Grösse der Nieren nach rascher und langsamer Injektion dieses Kontrastmittels gemessen. Die Bedeutung der Befunde für den fortdauernden Gebrauch des Iodipamids in der Röntgendiagnostik wird besprochen.

RÉSUMÉ

Le débit sanguin rénal a été étudié expérimentalement sur 10 chats après administration intra-artérielle et intraveineuse d'iodipamide. Six reins ont été examinés histologiquement. Les auteurs examinent la relation entre les effets observés et la vitesse d'injection. Ils ont mesuré les dimensions des reins chez des malades après injection rapide et lente de ce moyen de contraste. Ils examinent si ces résultats doivent empêcher de continuer à utiliser l'iodipamide en radiodiagnostic.

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Fig 2 Roentgen appearances suggesting tuberculosis Dilated calyces and irregularly outlined papillae Ureter with irregular borders follows a tortuous course

Urography and pyelography both demonstrated changes on the left side suggesting chronic inflammatory disease with blunting of the calyces and decreased cortical thickness Because of the unsuccessful catheterization of the right ureter a selective nephroangiography was done (Fig 1) The multiple filling defects in the nephrogram and the tapering and displacement of the vessels were interpreted as due to hydronephrosis Following angiography a second attempt at retrograde urography was made and this was successful (Fig 2) Extensive destruction of the collecting system was seen but the appearance was not compatible with angiographic evidence of hydronephrosis There was marked ureteral stricture and deformity (Fig 3 The most likely diagnosis on the basis of the retrograde pyelograms was tuberculosis One week after angiography a right nephrectomy was performed The pathologic diagnosis was xanthogranulomatous kidney The patient was discharged asymptomatic and remained so for the three months following surgery

Common signs and symptoms The disease occurs chiefly in adults and women predominate — This is commensurate with the higher incidence of pyelonephritis in females — A history of recurrent urinary tract infection with symptoms of dysuria frequency fever and chills is common Hematuria is rare A dull aching pain in the flank is a frequent complaint and in a significant number of cases a flank mass may be found on physical examination The most common organism cultured is *B proteus* (4 6) as in patients with pyelonephritis The laboratory examination is not specific and only the finding of a flank mass is suggestive of a xanthogranulomatous kidney



a



b



c

Fig. 1. Nephroangiography. a) Displacement and stretching of intrarenal arteries; absence of small peripheral branches; the capsule and ureteric branches are prominent. b) Late arterial phase. The branches are displaced by dilated calyces and granulomas; a mid renal branch is tortuous and becomes a capsular branch. c) The nephrographic phase simulates that of hydronephrosis or multiple cysts. These avascular areas are due in part to the calyces and in part to the granulomas.

The process may be very extensive and involve the entire kidney or may be localized to one portion of the kidney

As shown by angiography in this case, the vessels are attenuated and there is a lack of normal arborization of the peripheral branches The smaller arteries are displaced and in the nephrographic phase there are innumerable filling defects caused by the abnormal calyces and the xanthogranulomatous collections The overall angiographic appearance is most similar to that of hydronephrosis

Histologic examination of the enlarged kidney will show lipid laden cells (foam cells) giant cells in granuloma formation and cholesterol slits (4 7) (Fig 4) These changes are present in association with atrophic glomeruli and extensive fibrotic changes consistent with pyelonephritis Arteriolar nephrosclerosis is seen

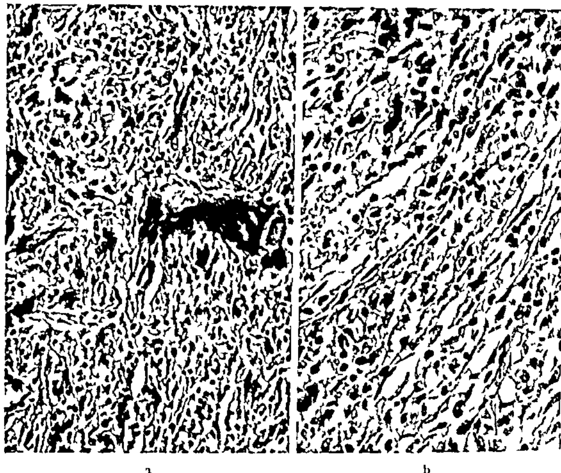
Discussion

The definition of the etiologic factors and pathogenesis of the xanthogranulomatous kidney is still awaited The relationship of xanthogranulamatous pyelonephritis to fibrolipomatous replacement of the kidney is uncertain (3 5 13) Both are related to chronic renal disease but the present concept is that the fatty replacement originates from the renal pelvis and sinus and is a replacement process associated with renal atrophy (10) A proposition that the one is a stage of the other has been offered (3) but this is hard to accept with the granulomatous process as a prominent feature of the xanthomatous reaction No one has shown a sequental change of this pyelonephritis into a fibrolipomatous kidney

The pyelographic and gross appearances are most reminiscent of tuberculosis or actinomycosis (2) Mycobacteria and fungi have been repeatedly sought but have never been found either in cultures or at histologic examination The most common organism found is *B proteus* but since this is common in chronic pyelonephritis it represents a secondary finding and it is not the etiologic agent of this form of pyelonephritis despite suggestions to the contrary

SUMMARY

Xanthogranulomatous pyelonephritis is an uncommon form of inflammatory disease of the kidney characterized microscopically by foam cells giant cells and cholesterol crystals The angiographic appearance in conjunction with the pyelogram is diagnostic alone it is highly suggestive of xanthogranulomatous pyelonephritis



a b

Fig 3 a) Giant cells are present as part of the inflammatory reaction Foam (lipid laden) cells can be seen × 300 b) Higher magnification shows the numerous lipid filled cells The nuclei are pyknotic × 500

Roentgen findings

The xanthogranulomatous form of pyelonephritis is a unilateral process but usually the opposite kidney is also affected by the inflammatory disease The film of the abdomen may reveal a large kidney The small atrophic kidney is not associated with this form of pyelonephritis Renal calculi are commonly seen, parenchymal calcification has not been noted On urography, characteristically but not invariably, secretion is not seen (4, 7) On pyelography, as in a chronically infected kidney, the renal cortical margin is reduced, and the calyces are blunted and irregular in outline The pyelographic appearance may well suggest tuberculosis, and this has been a point of confusion, especially in the earlier case reports Sometimes a renal mass is demonstrated, this has been termed tumefactive pyelonephritis (1, 8) (not seen in the present case)

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RENOVASCULAR HYPERTENSION AND WASHOUT UROGRAPHY

Preliminary results

by

KJELD ANDERSEN HANS KARLE and HANS WERNER

Urography permits assessment not only of the morphology of the urinary channels but also to a certain extent of the renal function In order to meet the increasing demands for ways of picking out cases with unilateral renal artery disease from among the large heterogenous hypertension group many attempts have been made in recent years to improve the urographic procedure and make it more suitable as a function test The object of this paper is to present our experiences

The most widely accepted view is that the primary effect of the stenosing factor upon renal function is a decrease in the renal blood flow, demonstrable by a reduction in the para aminohippuric acid clearance The immediate consequence is a lowering of the effective glomerular filtration which results in reduced production of ultrafiltrate on the stenosed side The tubules of the nephron will however to a marked extent function independently of this with the result that owing to the delayed passage of the ultrafiltrate there will

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ZUSAMMENFASSUNG

Xanthogranulomatose Pyelonephritis ist eine ungewohnliche Form von entzundlicher Nierenerkrankung. Sie ist gekennzeichnet durch Auftreten von Schaumzellen, Riesenzellen und Cholesterinkristallen. Das Angiogramm zusammen mit dem Pyelogramm gestattet die Stellung der Diagnose. Das Angiogramm allein ist sehr suspekt für xanthogranulomatose Pyelonephritis.

RÉSUMÉ

La pyélonéphrite xanthogranulomateuse est une forme rare d'affection inflammatoire du rein, caractérisée microscopiquement par des cellules spumeuses, des cellules géantes et des cristaux de cholestérol. L'aspect angiographique associé à la pyélographie donne le diagnostic; à lui seul il est très évocateur de la pyélonéphrite xanthogranulomateuse.

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Fig 1 Aortography in a 43 year old man with hypertension Stenosis of the right upper renal artery with post stenotic dilatation

also be emphasized that the demonstration of arterial stenosis is by no means proof of a causal relationship between the stenosis and the elevated blood pressure EYLER CLARK GARMAN KIAN & MEININGER (1962) have reported the results of aortography in 500 patients about half of those with renal arterial stenosis being normotensive Essential hypertension owing to the greater tendency to arteriosclerosis will presumably per se predispose to the formation of secondary functionally insignificant arterial stenoses

Ordinary urography if exposures are made 5 10 and 20 minutes after the injection of the contrast medium may show completely normal appearances despite the presence of occlusive vascular disease This phenomenon has been emphasized by MAXWELL (1962) and SQUIRE & SCHLEGEL (1959) among others POUTASSE (1961) states that even a scrupulous assessment of the shape of the kidneys and pelves will disclose pathologic changes in only 70 to 80 % of patients with renovascular hypertension and that furthermore a number of false positives must be expected According to POUTASSE, the most important criteria are (1) failing excretion of contrast medium despite a normal retrograde pyelogram (2) a difference of more than 1 cm in the size of the two kidneys to this may be added morphologic changes in the form of irregular outlines owing to cicatrization (following infarcts), (3) delayed excretion of contrast medium on one side (4) hyperconcentration of contrast medium on one side and (5) smaller dimensions of the calyces pelvis and ureter on one side which must be explained as a spatial adaptation to the reduced production of urine

Prompted by the difficulties encountered in diagnosing renovascular hypertension attempts have been made in recent years to alter the technique

be a relatively more complete reabsorption of water and salt This effect, however, decreases with decreasing renal flow, which gradually also comprises the blood supply of the peritubular area The ultimate result is invariably a decreased urinary output from the ischaemic side According to a recent publication by STAMEY (1963) this is the only decisive and invariable change of renal function in the disease The reduction is 50 % or over, as compared with the unaffected side (CONNOR, BERTHRONG, THOMAS & HOWARD 1957) In moderate degrees of ischaemia, the decrease is due principally to the increased reabsorption of water, while in severe cases the small quantity of ultrafiltrate is the decisive factor

Owing to the increased reabsorption of water, substances like creatinine *and inulin, which do not in themselves become reabsorbed, may be present in* higher concentrations in the urine from the stenosed than from the normal side This perhaps also explains the somewhat conflicting reports on the intensity of the contrast in the renal pelvis in conditions of this nature, as modern contrast media of the tri iodized type are mainly excreted by the kidneys through filtration without reabsorption (McCHESNEY & HOPPE 1957) In cases with slight stenosis the possibility of concentration of the contrast medium due to reabsorption of water may arise In the presence of very severe stenoses, on the other hand, only small amounts of contrast medium are filtrated per time unit, and *the pelvis will be less well filled, or no contrast* medium at all will be demonstrable

The induction of forced urinary output in the water tolerance test will, according to KJELLBO, VIKGREN, ÖMAN & HOOD (1962), accentuate the difference in the amount of urinary secretion on the two sides in the event of unilateral arterial stenosis Furthermore, BERLINER & DAVIDSON (1957) in experimental bilateral ureteral catheterization in dogs, demonstrated that the administration of urea will intensify this feature Urea in the normal kidney will increase the urinary output by osmotic action The slow passage of the *ultrafiltrate on the ischaemic side will however cause the excretion percentage* of urea to decrease, so that a larger quantity, and a correspondingly larger quantity of water, will be reabsorbed during the same time interval Such a difference will not be found with a substance exerting an osmotic action, such as mannitol, which in itself is not reabsorbed

Many authors claim that arteriography is the only diagnostic procedure that affords any means of disclosing renal artery stenosis This is of course true in so far as the purely anatomic verification is concerned, although it must be added that such verification may cause difficulty in the case of peripheral stenoses (e g fibromuscular hyperplasia) This procedure has some disadvantages as a routine investigation in hypertension, however It should



Fig 5 Washout urography in same patient as in figs 1 and 2 a) Clear films immediately before the washout b) Ten minutes later incipient dilution of the medium in left pelvis c) and d) Twenty and 55 min later Unchanged appearances on the stenosed side but a nearly complete washout on the left side

the two sides in the same individual when one kidney owing to arterial stenosis is functioning at a lower tension than the other SIGGERS has *reported* a case of his own with such a time difference in the excretion of the contrast medium in which aortography exhibited an atheromatous plaque *in the* renal artery on the delayed side following endarteriectomy resulting in a normal blood pressure simultaneous excretion on *the two sides was found* at repeat urography MAXWELL also had good *results from* extended urography with frequent exposures immediately after injection of the contrast medium Some workers (e g RATHE *1961*), *use* a large quantity of contrast medium and supplement by tomography stressing the importance of demonstrating a difference in the onset of the *nephrographic phase* Moreover a difference may also be demonstrated in the time that the medium remains in the renal pelvis MORRIS & DEBAKEY *(1962) therefore* recommended that this should be disclosed by late exposures

AMPLATZ (1962) described the technique of washout urography This method is based on the above *mentioned* facts concerning the urinary output in this disease and aims at demonstrating whether the induction of increased urinary output by rapid infusion of *physiologic* saline solution with urea results in an asymmetric washout of the contrast medium AMPLATZ had used

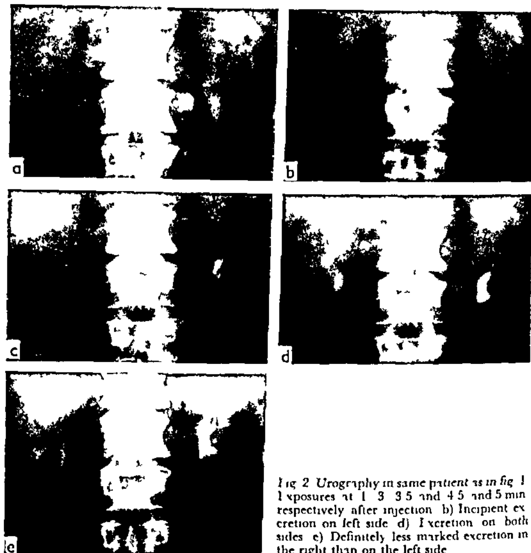


Fig 2 *Urography in same patient as in fig 1* Exposures at 1 3 3 5 and 4 5 and 5 min respectively after injection b) Incipient excretion on left side d) Excretion on both sides e) Definitely less marked excretion in the right than on the left side

of urography The role of arterial blood pressure in the excretion of contrast media by the kidneys has long been known WICKBOM (1950) has reported that there may be failing excretion in the pelvis during hypotension despite loading of the renal parenchyma, and EDLING, HELANDER & RENCK (1954) have demonstrated *experimentally that variations in arterial blood pressure are accompanied by alterations in the quantity of urinary secretion — a fact which is not difficult to understand if the significance of hydrostatic pressure* to glomerular filtration be recalled SIGGERS (1961), on the basis of 100 urographies with exposures once a minute during the first period after the injection of contrast medium, demonstrated that excretion from the renal pelvis began on an average one minute earlier in hypertensive than in normotensive subjects This difference would therefore be expected to manifest itself between

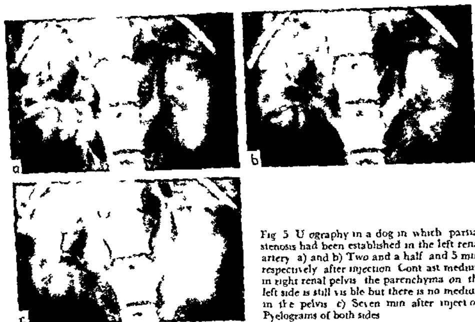


Fig 5 Urography in a dog in which partial stenosis had been established in the left renal artery a) and b) Two and a half and 5 min respectively after injection Contrast medium in right renal pelvis the parenchyma on the left side is still visible but there is no medium in the pelvis c) Seven min after injection Pyelograms of both sides

was symmetric in the great majority but two patients of this group had a delayed washout on one side

One of the above mentioned two patients was a 62 year-old man with a blood pressure of 250/120 mm Hg and serum creatinine of *1 2 to 1 4 in whom* aortography revealed stenosis of the renal artery on the delayed side The other patient was a 43 year old man whose blood pressure was 210/90 mm Hg and serum creatine *2 4 to 1 7 the* diastolic pressure was not definitely abnormal, possibly because of co existing aortic insufficiency Aortography disclosed stenosis of the upper and larger renal artery on the *right side (Fig 1)* close to its origin at the aorta and there was a post stenotic dilatation Urography with frequent exposures during the initial phase and the subsequent washout revealed delayed excretion as well as a greatly reduced washout on the right side (Figs 2 and 3)

Neither of these two patients was fit for operation In 10 of the other 20 patients aortography was performed without revealing any stenosis of the renal arteries

Experimental investigations *were performed* in an attempt to show a possible correlation between this excretion pattern and unilateral renal ischaemia Two examples are given below

1 A partially occluding plastic clamp was surgically applied under ether

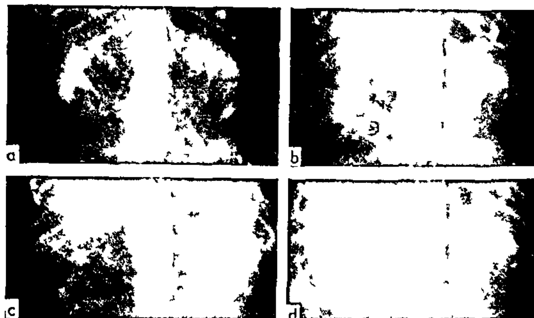


Fig. 1. Washout urography in a rat in which partial stenosis had been established in the left renal artery. a) Both renal pelves are filled with contrast medium. b) Two minutes after washout had started. Less dense film on right side. c) and d) Four and 6 min later. The left renal pelvis is still filled, the right pelvis has practically disappeared.

this procedure in 15 normotensive subjects, all of whom had symmetric washouts, while among 31 hypertensives three had delayed washout on one side where arteriography demonstrated stenosis of the renal artery. A surgical revascularization procedure on two of these patients abolished the hypertension, and subsequent washout urography no longer showed disparity between the two sides.

Present investigation

The authors have for some time been using frequent exposures during the first few minutes after the injection of contrast medium but have been able to demonstrate a time difference in the excretion of the contrast medium to the pelvis in only one out of 15 cases.

We use the procedure originally advocated by AMPLATZ for washout urography, only 10 ml and not 50 ml of one of the tri-iodized contrast media (Metriosat, Isopaque) are however injected. A few exposures are made during the first minutes, and when both pelves are sufficiently well outlined (usually in 10 minutes) an infusion of 500 ml physiologic saline solution and 10 g urea is started; the drip is completed within 15 to 20 minutes.

This method has been used in 11 normotensive subjects who had a symmetric and simultaneous washout. In a series of 20 hypertensive patients the washout

75 % with other conditions as above) was repeated under anaesthesia two weeks later The washout urography before the operation revealed symmetric dilution of the contrast within about 6 minutes An unmistakable time difference in the appearance of the contrast medium in the pelves during the excretory phase was apparent after the operation (Fig 5) and the subsequent washout disclosed distinct retardation in the dilution of the medium on the surgically treated side (Fig 6)

Conclusions

A simple method for selecting hypertensive patients would appear to be desirable Washout urography being based on well known pathophysiologic factors may be regarded as a radiologic split function test, and would appear to be a step on the way to a reasonable solution of the problem It is a diagnostic procedure which is easy to perform and to which all patients can be subjected By disclosing the characteristic ischaemic pattern it affords more effectively than arteriography, a possibility of demonstrating a causal relationship between arteriostenosis and hypertension

Only a possible relation between unilateral renal ischaemia and this excretion pattern is suggested by the above experimental investigations It is of course a totally different matter to decide whether such ischaemia is invariably accompanied by hypertension or conversely whether renovascular hypertension is always accompanied by renal ischaemia demonstrable by this method

The value of washout urography cannot be finally assessed from the present findings It seems a promising method for demonstrating functional disturbances due to diminished blood flow to the kidney, although bilateral affections still give rise to considerable diagnostic problems

SUMMARY

The value of arteriography and standard urography in diagnosing renovascular hypertension is discussed Washout urography aiming at establishing whether forced urinary output causes asymmetric dilution in the presence of unilateral renal arterial stenosis was performed in normotensive and hypertensive patients Two of the 20 hypertensive patients had evidence of asymmetric washout and on the delayed side aortography disclosed stenosis of the renal artery

ZUSAMMENFASSUNG

Der Wert der Arteriographie und der gewohnlichen intravenosen Urographie in Fallen von renal arteriellem Hochdruck wird besprochen Durchspuhlungs-Urographie mit dem Ziel zu bestimmen ob forcierte Ausscheidung asymmetrische Verdunnung des Kontrast

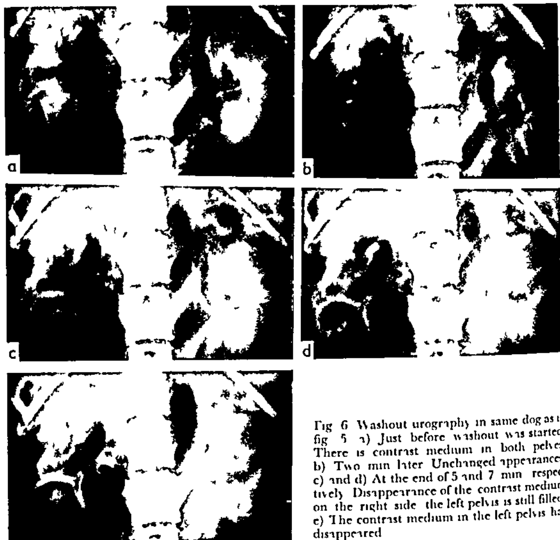


Fig 6 Washout urography in same dog as in fig 5 a) Just before washout was started There is contrast medium in both pelves b) Two min later Unchanged appearances c) and d) At the end of 5 and 7 min respectively Disappearance of the contrast medium on the right side the left pelvis is still filled e) The contrast medium in the left pelvis has disappeared

anaesthesia to the left renal artery in a rat weighing about 200 g About two weeks later washout urography (1 ml Isopaque 45 % and a subsequent injection of 2 ml NaCl 0 9 % with 150 mg urea) was performed under amytal anaesthesia The washout, which started when both renal pelves were distinctly outlined, disclosed complete clearing of the contrast medium on the right side while the left pelvis (the stenosed side) was distinctly filled for a long time (Fig 4)

2 Washout urography was first performed under nembutal anaesthesia in a dog of 14 kg (8 ml Isopaque 45 % and a subsequent infusion of 100 ml NaCl 0 9 % with 8 g urea) A few days later a clamp was applied to the left renal artery under nembutal anaesthesia, this was estimated to reduce its lumen to about 30 % of the normal The washout urography (8 ml Isopaque

75 %, with other conditions as above) was repeated under anaesthesia two weeks later The washout urography before the operation revealed symmetric dilution of the contrast within about 6 minutes An unmistakable time difference in the appearance of the contrast medium in the pelves during the excretory phase was apparent after the operation (Fig 5), and the subsequent washout disclosed distinct retardation in the dilution of the medium on the surgically treated side (Fig 6)

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mittels hervorruft wurde an Gruppen von Patienten mit normalen und erhohtem Blutdruck vorgenommen Zwei von den 20 Patienten mit erhohtem Druck zeigten asymmetrische Ausscheidung und auf der Seite der Verzogerung wurde eine Stenose der Nierenarterie gefunden

RÉSUMÉ

Les auteurs examinent la valeur de l artériographie et de l urographie ordinaire pour le diagnostic de l hypertension de cause vasculaire rénale Ils ont fait des urographies avec hyperhydratation chez des sujets normotendus et hypertendus pour établir si une excrétion urinaire forcée donne lieu à une dilution asymétrique en cas de sténose artérielle rénale unilatérale Deux des vingt malades hypertendus présentaient une dilution asymétrique et du coté ou la dilution était retardée l aortographie a montré une sténose de l artère rénale

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FROM THE EDWARD MALLINCKRODT INSTITUTE OF RADIOLOGY WASHINGTON UNIVERSITY SCHOOL OF MEDICINE, SAINT LOUIS, MISSOURI U S A

ANGIOCARDIOGRAPHIC MEASUREMENTS IN CONGENITAL HEART DISEASE

III Size of left ventricle including analysis of normal ventricular volume in systole and diastole

by

HAKAN ARVIDSSON

The left ventricle as a pump for the systemic circulation has to adapt itself to wide variations in circulatory demands The output and mode of adaptation may be studied by several methods the simplest is the minute volume determination by the Fick method or by the indicator dilution technique These give the cardiac output and by dividing it by the heart rate the stroke volume can be calculated Direct volume determinations of the end diastolic and end systolic volumes of the left ventricle by means of angiocardiography provide a new dimension in the analysis of left ventricular function and if no shunt nor valve incompetence is present it is also possible to determine the output The object of the present study was to analyze how the end systolic and end diastolic volumes are altered by common types of congenital heart disease The effect of a left to right shunt at the ventricular or aortic level is of special interest as a constant reduction of the left ventricular output then occurs i e

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Table 1

Survey of the patient material

	Normal	Pulmonary stenosis	Ventr septal defect (low pressure)
BSA m²	1.50 ± 0.36	0.91 ± 0.29	0.78 ± 0.3[illegible]
Heart rate	93 ± 18	100 ± 16	106 ± 28
LVmax ml/m² BSA	72 ± 11	69 ± 10	94 ± 19
LVCI	*4.86 ± 1.[illegible]3*	*4.78 ± 0.88*	*6.8[illegible] ± 2.01*
Flow pulmonary/ systemic (p/s)	—	—	1.96 ± 0.81
LVCI/p/s	4.86	4.78	3.[illegible]
Number of patients	11	12	22

Abbreviations LVmax ml/m² BSA = maximum diastolic volume of the left ventricle divided by the body surface area m² LVCI = left ventricular cardiac index The left ventricular minute volume in liter divided by body surface area or (LVmax—LVmin) freq/m² BSA Flow pulmonary/systemic (p/s) is the quotient between pulmonary and systemic flow as determined from the oximeter readings LVCI/p/s = an attempt to correlate the left ventricular cardiac index to the degree of shunting

only a certain proportion of the left ventricular stroke volume is pumped into the systemic circulation

The left ventricle normally contains a small amount of residual blood at the end of ventricular systole (LV_{min}) In a study of the left ventricular volumes in adult material (ARVIDSSON 1961) it was observed that a relationship existed between the maximum and minimum volumes of the left ventricle The diastole-systolic volume relationship was also analyzed in the present material

Material and Methods The basic patient material was the same as in the two previous studies on aortic size and left atrial volume (ARVIDSSON 1963, 1964) Several patients had to be excluded from the material, however, because it was impossible to determine the left ventricular volume This was true for all patients with tetralogy of Fallot in which the left ventricle was poorly delineated Simultaneous filling of the two ventricles also frequently hindered the volume determination Some patients from other diagnostic groups had to be excluded, either because of inadequate filling of the left ventricle, or because no films were obtained at the end of systole and diastole The remaining material comprised 71 patients, 11 were considered normal (N), 12 had pulmonary stenosis (PS), and 22 patients had ventricular defect with a pulmonary systolic pressure lower than 50 (VSDL) Four patients had a ventricular septal defect with a pulmonary systolic pressure higher than 50 (VSDH),

Table 1 *(cont)*

Ventr septal defect (high pressure)	Aortic stenosis	Patent ductus arteriosus	Ventr septal defect + patent ductus arteriosus	
0 52 ± 0 13	1 15 ± 0 23	0 55 ± 0 23	0 36 ± 0 16	
134 ± 28	98 ± 19	127 ± 30	136 ± 22	
140 ± 58	67 ± 9 7	117 ± 36	126 ± 14	
10 8 ± 4 5	4 4 ± 1 37	8 95 ± 2 78	10 77 ± 1 72	
2 25 ± 1 47	—	2 88 ± 1 55	3 48 ± 2 64	
4 8	4 4	3 1	3 1	
4	6	10	6	Total 71

6 had aortic valvular stenosis (AoS), 10 had a patent ductus arteriosus (PDA) and 6 patients had a ventricular defect combined with patent ductus arteriosus (VSD + PDA) (Table 1)

The equipment used for angiocardiography as well as the angiocardiographic technique were described in detail in an earlier paper in this series (ARVIDSSON 1963)

Left ventricular volume determination was carried out by a method described earlier (ARVIDSSON 1958 1961) but the principles will be briefly delineated The left ventricle was considered as a regular ellipsoid and from its axes measured in the a p and lateral films the volume was ascertained In the adult material studied earlier it was possible to use a standard magnification factor for compensation of the geometric distortion caused by the divergence of the roentgen rays

In the present material with the considerable variation in patient size it was however necessary to determine the magnification factor individually This compensation was carried out by the following approximation method (see Fig 1) A B S_1 and S_2 are known distances and in order to ascertain the magnification factors (f_1 and f_2) M and N have to be calculated C and D can be determined directly on the films (C is from the centre of the ventricular ellipse to the edge of the film in the lateral projection and D is the corresponding distance on the a p projection) Now if N is considered equal to $C + S_1$ and M equal to $D + S_2$ which means a slight approximation the magnification in the a p projection will be

$$f \approx \frac{B}{B - C - S_1} \text{ and in the lateral projection } f_2 \approx \frac{A}{A - D - S_2}$$

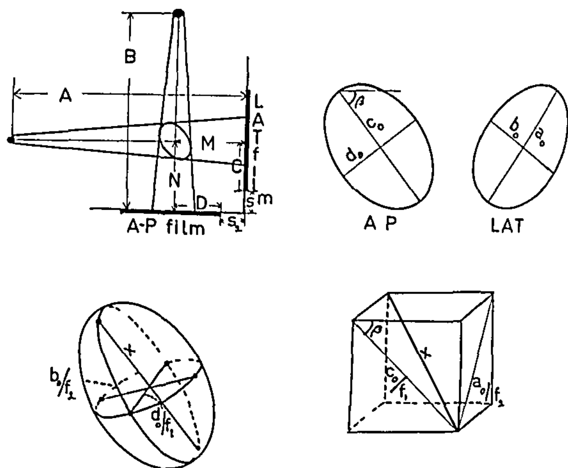


Fig. 1. *Left ventricular volume calculation with correction for geometric distortion. Top left:* Left ventricle in position for angiocardiography between the two film planes. *Top middle and right:* The ventricular ellipsoid in a.p. and lateral projections. *Bottom left:* Geometrically corrected ellipsoid with its long axis obtained from the diagram (*bottom right*) where the corrected long axis projection of the ellipsoid (C_0/f_1 and a_0/f_2) are put as diagonals in a parallelepiped. The axis x is the long diagonal of the parallelepiped and is obtained by simple stereometric calculation (see text).

According to the formula for the ellipsoid, the volume of the left ventricle will be

$$V = \frac{\pi}{6}\frac{b_0\, d_0}{f_1\, f_2}\left(\frac{c_0^2 \cos^2\beta}{f_1^2} + \frac{a_0^2}{f_2^2}\right)^{\frac{1}{2}}$$

d_0 and b_0 are the short axes measured on the a.p. and lateral films, respectively, and c_0 and a_0 are the projections of the long axis of the ellipsoid in the a.p. and lateral films (see Fig. 1).

For a more detailed analysis of the theory of correcting for geometrical distortion, the reader is referred to excellent papers on this subject by DODGE et coll., BRUCE & CHAPMAN, and by CHAPMAN et coll.

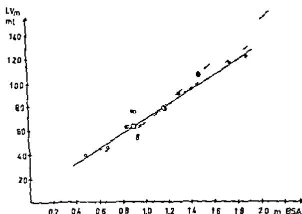


Fig 2 Relationship between body surface area and LVm Normal cases (filled circles) pulmonary stenoses (unfilled circles) and aortic stenoses (crossed circles) The broken line is the linear regression for the normal and the solid line the regression for the pulmonary stenosis material the broken-dotted line is the common regression line for the two materials The regression line for aortic stenosis is not drawn but all patients fall very close to the common regression for the other two materials

From a simultaneous ECG and exposure recording it was possible to determine which film pairs were optimal for the determination of the left ventricular stroke volume (end of systole LV_m and end of diastole LV_{ma}) The ECG recording was also used for the determination of the heart rate during angiocardiography The minute volume of the left ventricle could be determined by multiplying the stroke volume of the left ventricle by the heart rate There was unfortunately no opportunity to determine the effective left ventricular output simultaneously e g by indicator dilution techniques The degree of shunting in the patients with a left to right shunt was determined from blood oxygen determination with a Waters Conley cuvette oximeter (for details, see ARVIDSSON 1963)

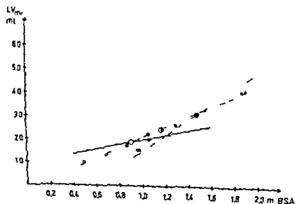


Fig 3 Relationship between body surface area and LVm Symbols are the same as in fig 2 The aortic stenosis patients also fall close to the common regression line for the normal and pulmonary stenoses patients

Results

A *General results* The general results from the measurements are surveyed in Table 1, which gives the mean and the sample standard deviations (s) (SNEDECOR) The body surface area was larger in the normal patients and in those with aortic stenosis than in the other diagnostic groups The smallest patients fell in the group with combined defects The heart rate was higher in the smaller patients, the relationship between body surface and heart rate during angiocardiography is shown in Fig 8 The left ventricular cardiac index (LVCI) is the left ventricular minute volume per square meter body surface area and was determined from the maximum and minimum left ventricular volumes, heart rate and body surface area LVCI is equal to the cardiac index in patients without shunts The values obtained for the cardiac index in these subjects are somewhat high as compared with the observations by other investigators (BROTMACHER & DEUCHAR, DEUCHAR & KNEBEL, KJELLBERG et coll , JEGIER et coll) The reason for this discrepancy may be an increased output during angiocardiography There might also be a systematic error in the method of volume determination (DODGE et coll and ARVIDSSON & KARNELL 1964)

B *Left ventricular size in normal cases, pulmonary stenoses and aortic stenoses* The maximum and minimum left ventricular volumes in pulmonary stenoses, aortic stenoses and normal patients were correlated to body surface area as demonstrated in Figs 2 and 3 A linear correlation with a relatively high correlation coefficient existed between LV_{max} and body surface area The linear correlation was not as high between LV_{min} and body surface area especially in the pulmonary stenosis group ($r = 0\ 36$) This was undoubtedly due to a greater error in volume determination for LV_{min} than for LV_{m}

Table 2

Mean left ventricular maximum and minimum volumes per m² of body surface area

	LVmax ml/m² BSA	LVmin ml/m BSA
N	72	20
PS	69	21
VSDL	94	30
AoS	67	21
VSDH	140	56
PDA	117	41
VSD + PDA	*126*	45

A co variance analysis was performed between the results in the normal group and the pulmonary stenosis group, it showed that there was no statistical difference The common linear regression equations were determined It is obvious from the figures and the regression equations that the patients with aortic stenosis do not differ from those of the normal material and the pulmonary stenoses The following regression equations were obtained

Normal	$LV_{max} = 104\ 6 + 83\ 5\ (BSA - 1\ 48)$	11 obs	$r = 0\ 81$
Pulmonary stenosis	$LV_{max} = 62\ 2 + 53\ 9\ (BSA - 0\ 91)$	12 obs	$r = 0\ 90$
Common regression	$LV_{max} = 81\ 5 + 73\ 3\ (BSA - 1\ 17)$ or approximated $LV_{max} \approx 4\ (18\ BSA - 1)$	23 obs	
Aortic stenosis	$LV_{m} = 77\ 5 + 73\ 9\ (BSA - 1\ 15)$	6 obs	$r = 0\ 90$
Normal	$LV_{m} = 30\ 4 + 33\ 3\ (BSA - 1\ 48)$	11 obs	$r = 0\ 79$
Pulmonary stenosis	$LV_{min} = 18\ 6 + 10\ 6\ (BSA - 0\ 91)$	12 obs	$r = 0\ 36$
Common regresssion	$LV_{min} = 24\ 0 + 21\ 9\ (BSA - 1\ 17)$ or approximated $LV_{min} \approx 2\ (11\ BSA - 1)$	23 obs	
Aortic stenosis	$LV_{min} = 24\ 6 + 29\ 0\ (BSA \approx 1\ 15)$	6 obs	$r = 0\ 96$

The discussion and formulae may be summarized as follows

1 A linear relationship exists between both left ventricular maximum and minimum volumes and bodily development expressed as body surface area

2 The linear relation is the same for normal pulmonary stenoses and aortic stenoses patients

C *Left ventricle in cases with left to right shunt* The patients with a left to right shunt had significantly greater relative diastolic and systolic volumes than those without a shunt (see Table 2)

The relation between the normal regression and the patients with shunt is shown in Fig 4 All patients with shunts, except two fall above the normal regression line The spread of the observation is rather marked and as for the left atrial volume it was expected that the volume of the left ventricle

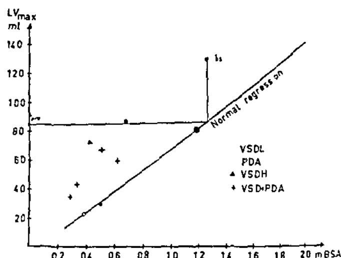


Fig. 4. Left ventricular maximum volume related to body surface in cases with left to right shunts. Normal regression line obtained from the normal and pulmonary stenosis patients (fig. 2), all of whom except two fall above the normal regression. The spread of the observations is marked. The method for determining the predicted from the observed left ventricular volume is demonstrated.

was partly governed by the degree of shunting. The linear regression was therefore calculated between the left ventricular maximum volume on one hand and the body surface area and the shunt on the other. The degree of shunting, as earlier, was expressed as the quotient pulmonary/systemic flow.

The regression equations obtained are given in Table 3. The correlation coefficients are reasonably good but the improvement in correlation obtained by the addition of the second independent parameter (p/s) was relatively slight, probably due to the unrefined method of determining the shunt. It was, however, possible to prove that the left ventricle dilates more or less proportionally to the shunt.

The method used was similar to the one employed for left atrial size (ARVIDSSON 1964). The predicted left ventricular diastole volume in each case was determined in Fig. 4 by passing from the individual observation vertically *to the regression line of the normal material.* The quotient 'observed/predicted left ventricular volume' was calculated and plotted against the quotient 'pulmonary/systemic flow' (Fig. 5). The dispersion of the values is marked,

Table 3

Left ventricular maximum related to body surface area and degree of shuntin

VSDL	$Y = 73.59 + 87.59\,(X_1 - 0.80) + 6.74\,(X_2 - 1.96)$ 22 obs $r = 0.87$
VSDH	$Y = 67.00 - 18.12\,(X_1 - 0.52) + 3.52\,(X_2 - 2.25)$ 4 obs $r = 0.50$
PDA	$Y = 64.60 + 128.10\,(X_1 - 0.55) + 10.71\,(X_2 - 2.88)$ 10 obs $r = 0.96$
VSD + PDA	$Y = 41.71 + 82.88\,(X_1 - 0.36) + 2.90\,(X_2 - 3.14)$ 7 obs $r = 0.94$

Abbreviations: Y = LVmax, X_1 = BSA in m², X_2 = degree of shunting expressed as pulmonary/systemic flow, r = linear correlation coefficient

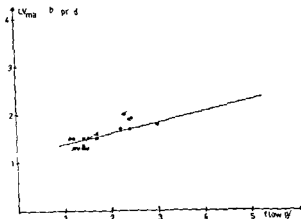


Fig 5 Relationship between left ventricular enlargement and the degree of shunting Observed left ventricular volumes divided by the predicted volumes (see fig 4) related to the degree of shunting expressed as pulmonary/systemic flow Two regression lines are drawn the solid line is for the whole material $Y = 1\ 62 + 0\ 21\ X$ ($r = 0\ 56$) and the broken line is the regression for patients with shunts less than 3/1 $Y = 0\ 67\ X + 0\ 51$ ($r = 0\ 59$) The latter regression falls relatively close to a 45 inclination

and the linear coefficient or correlation is low $r = 0\ 56$ It is noticeable that among the smaller shunts the two quotients run more or less parallel (see Fig 5 where the regression line is also drawn for the cases with shunts less than 3/1) The left ventricle does not dilatate as much in the patients with large shunts (For possible explanations to this observation see below under discussion)

Similar results were obtained for the left ventricular minimum volume but the dispersion of the values were even higher This fact was no doubt due to the greater error in the primary volume determination

The difference in heart rate was not taken into consideration in the above discussion An attempt was made to compare the left ventricular cardiac index to the shunting The left ventricular cardiac index divided by the shunting is given in Table 1 The values obtained were lower than the ones in the patients without shunts except in the VSDH group — this is discussed later The observations regarding patients with a left to right shunt may be summarized as follows

1 The relative end diastolic as well as the end systolic volumes of the left ventricle are increased when compared with patients without a shunt

2 The volume shows a linear correlation to the parameters body surface area and shunting expressed as pulmonary/systemic flow

3 The enlargement of the left ventricle runs parallel to the degree of shunting in the small and intermediate shunts ($p/s < 3$)

4 Among the large shunts ($p/s > 3$) the left ventricle does not dilatate proportionally to the shunt although there is a tendency to larger ventricles in larger shunts

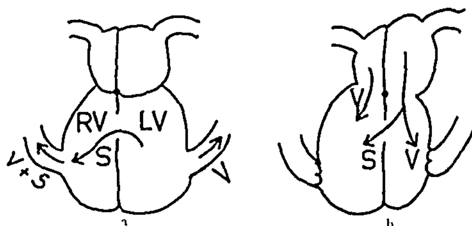


Fig. 6. The effect of the shunt timing in ventricular septal defect. *V* is the systemic stroke volume and *S* the shunted volume per stroke. a) 100 % systolic shunting. *The stroke volume of the left ventricle is V + S and for the right ventricle V.* b) 100 % diastolic shunting. The stroke volume of the left ventricle is V and for the right ventricle $S + V$. $\frac{S+V}{V} = p/s$ and furthermore

$$\frac{S+V}{V} = \frac{\text{observed left ventricular volume}}{\text{predicted left ventricular volume}}$$ with the shunting 100 per cent systolic.

Discussion

Interpretation of left ventricular size in conventional films. No attempt was made to correlate the left ventricular size, as obtained from the volume calculations, to the conventional film interpretation. Most investigators on this subject agree that the interpretation of the left ventricular size from the conventional film is extremely difficult, especially when right ventricular enlargement is also present (KJELLBERG et coll., and JONSSON).

An important source of error in the interpretation is that the films are usually obtained at random in the heart cycle. It is, however, sometimes possible to discern a left ventricular dilatation in patients with a left to right shunt at the ventricular or aortic level. KEATS et coll. reported 65 per cent left ventricular enlargement in ventricular septal defects.

The left ventricular cavity in the present series is of normal size in the patients with aortic stenosis. It is, however, well known that in many but not all, patients with aortic stenosis, the left ventricle has abnormal contours in the conventional films (JONSSON, KJELLBERG et coll., TAUSSIG) and, since no dilatation is present, this must be due to the hypertrophy of the left ventricular wall. The left ventricle is of normal size in pulmonary stenosis as might be expected, the haemodynamics of the left side of the heart is normal in pulmonary stenosis with a normal output at rest, except possibly in cases of extreme pulmonary stenosis (RUDHE et coll.).

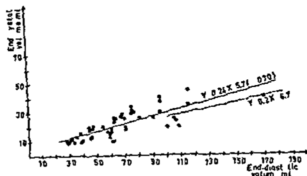


Fig 7 Relation between end-diastolic and end systolic volumes of the left ventricle The individual case represented by a black circle The solid line is the linear regression for the present material A material of 16 adult patients mainly with rheumatic heart disease is indicated for comparison by the regression of the broken line There is very little difference between the two regressions

Left ventricle in left to right shunts There are three principally different types of left to right shunts as far as the effect on the left ventricular size is concerned viz shunts at the atrial level (ASD and pulmonary anomalous venous return) at the ventricular level (VSD), and shunts at the aortico pulmonary level (PDA and pulmonary aortic window)

The increased load caused by a shunt at the atrial level does not affect the left ventricle except when the shunt is very large so that the systemic output is decreased even at rest in which case the left ventricle is smaller than normal Unfortunately it was impossible to calculate the left ventricular volume on the available material of atrial septal defects since the examinations were made in oblique position

The way the shunting affects the left ventricular size in ventricular septal defect is complex and depends on the heart phase or phases in which shunting occurs Two extreme possiblities are sketched in Fig 6 in which the shunting is 100 per cent systolic and 100 per cent diastolic, respectively In the first alternative the left ventricle dilates proportionally to the degree of shunting and the volume of the right ventricle remains unchanged or is possibly only slightly increased In the second alternative, when the shunt is 100 per cent diastolic the shunted blood passes directly over from the left atrium to the right ventricle without increasing the volume load on the left ventricle The right ventricle in this case dilates proportionally to the shunting and the left ventricle remains unchanged in volume In reality, both systolic and diastolic shunting may occur even if the gradient usually favours the systolic shunting The results obtained from the present studies also indicate that the systolic shunting predominates in ventricular septal defect since the left ventricle dilates proportionally to the shunt, at least when the shunt is moderate The relatively smaller increase of left ventricular volume in the large shunts

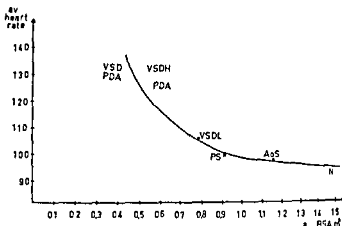


Fig 8 Average heart rates within the diagnostic groups plotted against body surface area A logarithmic relation appears to exist within the range studied between the two parameters

may be due to increased diastolic shunting (e g by increased diastolic pressure in the left ventricle) Another explanation to the deviation may be that the output into the aorta is reduced in large left to right shunts

A column is designed $LVCI_{p/s}$ in Table 1, which means the left ventricular minute volume per m² BSA divided by the degree of shunting If it is assumed that the output into the aorta is the same in the shunt cases as in the cases without shunts, and that the shunting is 100 per cent systolic in the groups with ventricular septal defect, the quotient $LVCI_{l/s}$ would be the same in all diagnostic groups Now, LVCI in the patients without shunts is roughly 4 8 liters $LVCI_{l/s}$ is 3 5 l in VSDL, 4 8 l in VSDH, and finally in the groups with PDA and VSD + PDA it is 3 1 l This means that within the VSDL groups either the shunting is partly diastolic (calculated from the values, 34 per cent diastolic shunting), or with 100 per cent systolic shunting the output must be reduced to 3 5 l/m² BSA The reduction may also be due to a combination of these two factors In the patent ductus arteriosus patients no reduction can occur from the timing of the shunting, so it must be due to a decrease in systemic output The error in measuring the shunt is however considerable in patent ductus arteriosus due to the incomplete mixing at the site of pulmonary artery sampling

Relationship between systolic and diastolic volumes of the left ventricle The systolic and diastolic volumes were shown to have a linear relation in adult material without mitral or aortic insufficiency (Arvidsson 1961, Arvidsson & Karnell 1961)

An analysis of the volume quotients in the present material disclosed that there was also a linear correlation and that no statistically significant difference existed beween the various diagnostic groups In Fig 7 the individual observa

tions are plotted and the linear regression is indicated (solid line) The linear regression from the above mentioned adult material is also drawn for comparison (dotted line) the similarity is remarkable It may be mentioned that in an adult material of mitral and aortic insufficiency (ARVIDSSON & KARNELL 1964) another relationship was found with relatively larger end diastolic volumes A similar relative increase of the end diastolic volumes could be expected in left to right shunts since in this condition there is an increased volume load on the left ventricle Such an increase was not found however and a possible explanation is that the volume load was higher in the adult material Another possibility could be that the duration of the condition was much longer among the mitral and aortic disease patients

Heart rate during angiocardiography in relation to body surface area It is evident from Table 1 that the heart rates within the different diagnostic groups increase with decreasing surface area The average heart rates were plotted against the average body surface areas within the different groups in order to clarify this relationship (Fig 8) Within the actual range exponential relationship appears to exist between the two parameters the observation is only of limited value however since the heart rates are recorded during angiocardiography with all the aberrations due to the standard conditions involved in this procedure

Acknowledgement

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SUMMARY

Sixty patients with congenital heart disease and 11 normal patients were studied angiocardiographically The ventricular volume was calculated at the end of systole and diastole A linear relationship was found between the left ventricular size and body surface area The left ventricle was enlarged in the patients with left to-right shunts the enlargement being roughly proportional to the degree of shunting

ZUSAMMENFASSUNG

Sechzig Falle von angeborenen Herzfehlern und 11 normale Falle wurden mittels Angiocardiographie untersucht Das Kammervolumen wurde am Ende der Systole und der Diastole bestimmt Es zeigte sich dass ein geradliniges Verhaltnis zwischen der Grosse des linken Ventrikels und der Gesamtkörperoberflache besteht Der linke Ventrikel zeigte sich vergrossert wo ein links nach rechts shunt vorlag der Grad der Vergrösserung erwies sich ungefähr proportional dem Grade des shunt

RÉSUMÉ

Soixante malades atteints de cardiopathie congénitale et onze sujets normaux ont été étudiés par angiocardiographie. Le volume ventriculaire a été calculé à la fin de la systole et de la diastole. On a trouvé une relation linéaire entre le volume du ventricule gauche et la surface corporelle. Le ventricule gauche est augmenté de volume dans les cas de shunt gauche droite, l'augmentation de volume étant en gros proportionnelle à l'importance du shunt.

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ANGIOGRAPHY IN THREE CASES OF MUSCLE RUPTURE WITH ORGANIZING HAEMATOMA

by

BERTIL STENER and INGMAR WICKBOM

Angiography is used extensively in cases of probable soft tissue tumours of the extremities as it can assist in the diagnosis and provide valuable topographic information. A soft tissue tumour may contain few vessels or it may be highly vascular. ROSCH (1964) maintained that in the former type *the question of* malignancy cannot be settled by angiography, whereas, assuming that a haemangioma can be eliminated, the demonstration of a *highly vascular* tumour in itself suggests malignancy. It must be noted, however, that other benign soft tissue tumours, e. g. hibernoma (ANGERVALL, NILSSON & STENER 1964), may also be highly vascular. Moreover, the angiographic appearances of inflammatory processes may sometimes resemble those in highly vascular malignant tumours; such cases have been reported by LAGERGREN, LINDBOM & SODERBERG (1958), MARGULIS & MURPHY (1958), SUTTON (1962) and COCKSHOTT & EVANS (1961). The present authors have observed several cases of this type, e. g. an infected bursa at the elbow.

This communication describes a further non-neoplastic disorder that may

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Fig 1 Case 1 Muscle rupture with organizing haematoma Femoral angiography 1 week after onset frontal (a) and lateral slightly later phase (b) Streaky accumulation of medium at the site of the distal part of the vastus lateralis m just above the patella Veins from the periphery of the region filled in the arterial phase (arrows) The histologic examination (c) (× 133) disclosed highly vascular granulation tissue





Fig. [illegible] Case 2. Muscle rupture with organizing haematoma. Femoral angiography [illegible] weeks after onset with 3 sec intervals between the films of (a), (b) and (c). A streaky [illegible] 8 × 5 cm collection of contrast medium is seen at the site of the vastus medialis [illegible]. Veins in the periphery of the region started to fill at an early stage. The femoral vein (upper arrow) started to fill while there was still contrast medium in the femoral artery (lower arrow). Femoral angiography 8 weeks after onset (d), with film obtained at a phase between those of (a) and (b), showed *almost* complete regression of the changes observed 6 weeks earlier.

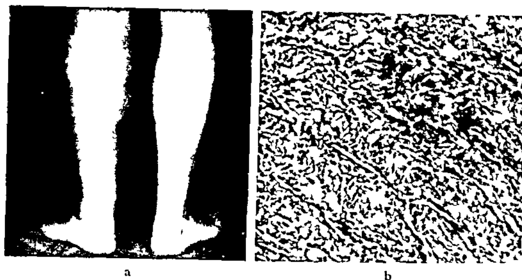


Fig 3 Case 3 a) The patient six weeks after onset the circumference of the left calf is 4 cm greater than that of the right calf b) Histologic examination was performed 3 days after the angiographic examination Highly vascular granulation tissue from the wall of the haematoma cavity × 113

sometimes be difficult to differentiate from a highly vascular tumour by means of angiography, i e muscle rupture with organizing haematoma Angiography in highly vascular tumours generally discloses a rapid passage of the contrast medium to the venous side, this was also observed in the three cases now reported

Case reports

Case 1 (Fig 1) Male aged 24 dock labourer with a lump initially tender in the lateral part of the right thigh just above the knee joint No history of trauma

Angiography was performed a week after the first appearance of the swelling (Fig 1 a and b) The contrast medium accumulated in streaks and patches in a region measuring 6 × 4 × 3 cm, corresponding to the distal part of the vastus lateralis muscle and extending to just above the patella The afferent arteries appeared normal and no pathologic vessels were present The veins draining the region were filled with medium earlier than those from the adjacent musculature

The region was explored in a bloodless field a week later It was found that the lump was caused by a partial rupture of the vastus lateralis m with an organizing haematoma

The histologic examination (by I Zettergren) confirmed the findings at operation necrotic muscle and tendon fibres blood remnants fibrinous exudation and highly vascular granulation tissue (Fig 1c)

Case 2 (Fig 2) Male aged 50 clerk with a tender swelling on the medial aspect of the left thigh about 10 cm above the knee joint This had appeared a week previously and had gradually increased in size until it was about 8 cm in diameter No history of trauma

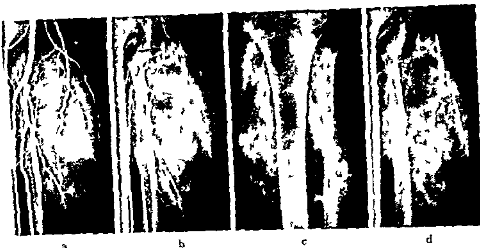


Fig 4 Case 3 Muscle rupture with organizing haematoma Femoral angiography 10 weeks after onset with 3 sec intervals between (a) (b) and (d) The frontal view (c) was obtained approx. in the same phase as the lateral view (b) Streaky collection of contrast medium size 16 × 13 × 10 cm at the site of the palpable lump the veins filled while there was still medium in the arteries at the same level (arrow)

Angiography was performed 2 weeks after the swelling first appeared (Fig 2 a b c) The contrast medium collected in streaks and patches in an area measuring 8 × 5 × 4 cm corresponding to the vastus medialis m with its center 15 cm above the knee joint The femoral artery was displaced medially and dorsally and its branches were curved around the region No other arterial changes were evident The veins in the periphery of the area filled sooner than others at the same level

Clinical examination on the same day as the angiographic examination disclosed an ovoid firm painless lump in the vastus medialis muscle apparently fastened to its deep surface A tumour was considered possible but on the other hand a patch of skin just below the knee had a bluish hue and the angiographic appearances were rather similar to those in Case 1 A preliminary diagnosis of muscle rupture with an organizing haematoma was therefore made and we decided to await developments The mass gradually regressed and at control angiography (Fig 2d) 8 weeks after its first appearance the changes noted earlier had almost entirely disappeared After 5 months a small firm area (probably scar tissue) was present deep in the vastus medialis muscle The course thus supported the diagnosis

Case 3 Figs 3 and 4) Male aged 32 marine engineer had received a blow on the left knee which became swollen Three weeks later he was admitted to hospital with thrombosis of the left calf he was then treated with heparin and dicumarol and discharged free from symptoms after a week Six weeks later he was readmitted with marked swelling and tenderness of the calf the circumference of which was 4 cm greater than that of the other side (cf Fig 3a) The treatment for thrombosis was reinstituted this time however the swelling did not regress

A lump gradually became more and more clearly defined in the calf and after 6 weeks the patient was referred to us A careful review of the history suggested a possible diagnosis of muscle rupture with an organizing heamatoma this was supported by the angiographic



Fig. 5. Femoral angiography in a case of malignant neurilemmoma of the tibial nerve; the interval between the two films was 2.5 sec. Clearly defined pathologic vessels in a 7 × 9 cm area in the popliteal fossa; diffuse accumulation of contrast medium caused by filling of numerous tumour vessels which were too fine to be evident macroscopically (confirmed by microangiography).

appearances which generally resembled those observed in Case 1 and Case 2. The mass did not regress noticeably and 4 weeks later it was decided to perform control angiography and then explore.

The *second angiographic examination*, which was carried out 10 weeks after the swelling had reappeared (Fig. 4), gave practically the same results as the first one (performed 4 weeks earlier). The contrast medium accumulated in a streaky and patchy area, measuring 16 × 13 × 10 cm and corresponding to the site of the mass, with its centre 12 cm below the knee joint. Stereoscopic films disclosed that the medium collected only in the periphery of the region. Both arteries and veins had a curved, somewhat elongated course round the outside of the region but there were no other vascular changes. The medium started to appear in veins draining the region before it had disappeared from the arteries at the same level in the leg.

Operation in a bloodless field 3 days after angiography confirmed the diagnosis of muscle rupture with organizing haematoma. The medial head of the gastrocnemius was partially ruptured (on its deep aspect) and old blood, some of it coagulated, filled a large cavity between the soleus m. and the bellies of the gastrocnemius. The haematoma was evacuated and some necrotic muscle tissue excised.

The histologic examination (L. Angervall) of tissues from the wall of the cavity disclosed highly vascular granulation tissue (Fig. 3b). The excised muscle tissue displayed haemorrhagic infarction.

Discussion

These 3 cases of muscle rupture with organizing haematoma presented similar angiographic appearances, characterized by (1) an accumulation of contrast medium (in streaks and patches) at the site of the palpable mass (2) absence of individually distinguishable pathologic vessels and (3) rapid passage of contrast medium to the venous side

The collection of contrast medium may be explained by abundance of capillary vessels in the granulation tissue that had formed around the haema toma (Figs 1c and 3b) The individual vessels in this tissue are too fine to be distinguishable at conventional angiography (cf MATTSSON 1955) but are so numerous that together they appear as dense streaks and patches In Case 3 in which the palpable lump was particularly large it was evident from the stereoscopic films that the medium accumulated only in the periphery, in keeping with this the central part of the mass was found to consist of old blood A collection of medium only in the periphery also occurs in cases of haemor rhage (or necrosis) in a tumour

None of the three cases presented pathologic vessels sufficiently large to be seen angiographically the medium appeared to pass straight from afferent arteries of ordinary appearance to the very fine macroscopically indistinguish able vessels responsible for its accumulation Malignant soft tissue tumours often though not always, present clearly definable pathologic vessels (e g Fig 5)

The rapid passage of contrast medium to the venous side particularly evident in Case 2 may at least in part — like the accumulation of contrast medium — be explained by the abundance of capillary vessels in the granula tion tissue (Preformed arteriovenous shunts opening in the periphery of the haematoma may conceivably have played a part as well) The arteriovenous shunting observed by LAGERGREN LINDBOM & SODERBERG (1958) at angio graphy in some cases of chronic inflammation was also held to be explained by an abundance of capillary vessels in granulation tissue These authors pointed out the difficulty of differentiating between inflammation and tumour in those cases in which angiography reveals arteriovenous shunting via vessels too small to be separately distinguished ($< 300\ \mu$) The present study indicates that it may also be hard to differentiate angiographically between muscle rupture with organizing haematoma and a tumour with no definable pathologic vessels

SUMMARY

The angiographic appearances in three cases of muscle rupture with organizing hematoma are described These are of practical importance and must not be confused with those produced by a malignant soft tissue tumour

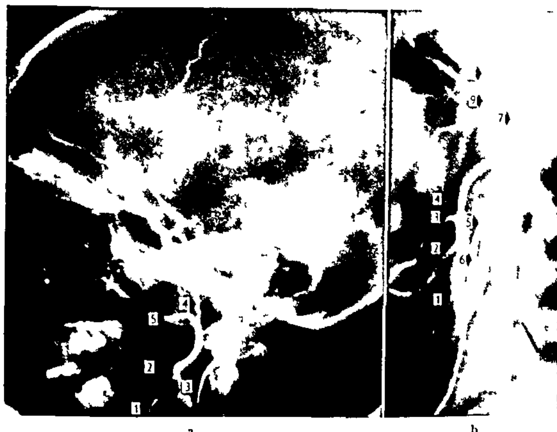


Fig. 1. a) Normal external carotid angiogram. The branches are labeled: (1) external maxillary, (2) ascending pharyngeal, (3) occipital, (4) superficial temporal, (5) internal maxillary. b) Normal external carotid angiogram: *catheter placed at carotid bifurcation to demonstrate* superior thyroid branch. Superior thyroid artery arises very close to bifurcation. In order to fill this vessel the contrast medium will usually reflux into the internal carotid artery. The respective branches are: (1) superior thyroid, (2) lingual, (3) external maxillary, (4) ascending pharyngeal, (5) occipital, (6) sternocleidomastoid, (7) posterior auricular, (8) superficial temporal, (9) internal maxillary.

ses. Examples were shown of meningiomas and dural metastases that could be accurately diagnosed by characteristic pathologic vessels. The extradural location of hematomas was confirmed. He succeeded in puncturing the external carotid artery in 58 out of 62 cases (RUGGIERO & JAN 1958, RUGGIERO et coll. 1963). Through personal communication, RUGGIERO reported investigators at other centers averaging about 80% success rate.

The external carotid artery begins at the bifurcation of the common carotid, near the upper border of the thyroid cartilage, passes through the carotid and retromandibular fossae to the level of the neck of the mandible where it divides into its terminal branches, the internal maxillary and superficial temporal arteries.

There usually are nine branches of the external carotid artery. They are

anteriorly the superior thyroid lingual and external maxillary posteriorly the occipital sternocleidomastoid and posterior auricular, ascending the ascending pharyngeal, and terminally the superficial temporal and internal maxillary The angiographic appearance of the normal external carotid angiogram is depicted in Fig 1 and the respective branches are labeled It is important to note the course of the different branches of this artery, because they can be selectively catheterized if desired to demonstrate a specific abnormality

In over 90 % of the patients the external carotid artery pursues a course anterior and medial to the internal carotid artery On the lateral projection the external carotid lies approximately 1 cm anterior to the internal carotid on a parallel course The a p projection will show that the external carotid is approximately 0 5 cm medial to the internal carotid initially and at the level of the external maxillary artery it sweeps laterally in a shallow curve until it lies lateral to the internal carotid as it enters the retromandibular fossa

With increasing age the configuration of the carotid bifurcation changes The external carotid artery tends to rotate medially, and the bifurcation is more Y shaped The internal carotid artery angulates posteriorly at about 90 degrees rather than the usual parallel course to the external carotid artery

The configuration of the carotid bifurcation is extremely important when selective catheterization of the internal and external carotid artery is under taken In young patients the vessels may lie immediately adjacent to each other and project exactly superimposed in the a p view With increasing age the plane of the internal and external carotid arteries changes so that they lie side by side in a horizontal plane In the average patient the lateral projection (or horizontal translateral fluoroscopy) is used to separate the two

Examination technic With the introduction of the catheter technic to carotid angiography (LIVERUD 1958) the demonstration of the internal and external carotid circulation was simplified (HANAFEE & WEIDNER 1963)

The common carotid artery is punctured percutaneously under local anesthesia low in the neck using a Wickbom needle with attached saline filled tubing The puncture site in the common carotid artery must be far enough below the bifurcation to enable maneuvering the catheter subsequently from the internal carotid artery to the external carotid or vice versa After successful arterial puncture has been accomplished preliminary simultaneous a p and lateral films of the neck vessels are made with a 4 ml injection of 50 % Hypaque The lateral film is a Polaroid and can be viewed in 11 seconds The a p film is a conventional roentgenogram processed in the automatic film processor to allow for greater detail in the film These preliminary films demonstrate the configuration and patency of the carotid arteries at their origin If the carotid



Fig. 2. Subtraction film of a selective external carotid angiogram in a 73 year old female with a history of a mass in the right frontoparietal area which had been enlarging slowly for the past year. Angiography revealed hypertrophy of the superficial temporal (←) and middle meningeal (+) arteries, numerous areas of puddling of contrast medium in the tumor vessels; the lumen of the small arterioles is irregular (↔) and shows alternate areas of widening and relative narrowing, allowing the preoperative diagnosis of a malignant tumor involving the meninges to be established. The pathologic diagnosis was malignant meningothelial meningioma.

bifurcation is patent, and no significant atherosclerosis exists in the vessels, a white polyethylene catheter (Becton, Dickinson) is introduced into the artery by a modified Seldinger technic. Injections of saline can confirm the position of the catheter. If the catheter is in the external carotid artery, blanching of the skin of the cheek and upper lip will be seen, and the patient will experience a sensation of cold in these areas; internal carotid injections will cause blanching of the inner canthus of the eye, and the patient may notice a cold sensation behind the eye.

Horizontal beam fluoroscopy is generally employed to position the catheter in the external carotid artery. The tip of the catheter is slightly curved. If the initial pass is into the internal carotid artery, the catheter lumen is filled with 50 % Hypaque to obtain visibility, and the tip is directed anteriorly. The catheter is withdrawn slowly to the bifurcation of the common carotid artery where a distinct flip is seen, and the catheter will then advance into the external carotid artery. In older patients, or in patients in whom the origin of the external carotid lies lateral to the internal carotid, vertical fluoroscopy may be necessary to maneuver the catheter. The preliminary films will give this information about the carotid bifurcation.



a b c

Fig 3 Carotid body tumor in a 38 year-old male with a 1 month history of excessive secretions in the throat a non productive cough and mild discomfort in the throat which increased with swallowing a) Selective carotid angiography by the catheter technic the catheter being positioned just below the bifurcation of the common carotid artery The vascular staining is apparent b) Selective internal carotid angiography revealed that the internal carotid artery did not contribute to the blood supply of this vascular tumor c) Selective external carotid angiography revealed that the tumor supply derived from the external carotid artery primarily from the superior thyroid and lingual branches

Clinical applications of the technic

Selective external carotid angiography is indicated in the following conditions (1) meningiomas (2) arteriovenous malformations of the soft tissues of the head and neck (3) intradural versus extradural hematomas (4) diagnosis of tumors of the soft tissues of the head and neck, (5) collateral circulation via the external carotid artery (6) occasionally the catheter may be left in place for the infusion of chemotherapeutic agents

Meningiomas are tumors from the arachnoid and more specifically the arachnoid villae The incidence and distribution corresponds to the distribution and relative number of arachnoid villae along the dural sinuses The rare intraventricular meningiomas probably arise from elements of arachnoid which are carried with the folds of pia mater which form the tela choroidea in which the chorid plexuses develop The blood supply of intracranial meningiomas has been described in detail by ROUKKULA & SALTZMAN (1963) SCHNURER & STATTIN 1963) WICKBOM (1953) STATTIN (1961) and WICKBOM & STATTIN 1958)



Fig 4 Same case as in fig 3 a) Vertebral angiography by the *catheter technic disclosed hyper trophy* of the first and second seg mental branches of the vertebral artery supplying the vascular tumor at the carotid bifurcation b) Se lective thyrocervical trunk angio graphy showed hypertrophy of the *profund cervical* branch supplying the vascular tumor at the carotid bifurcation

In general, intracranial, extracerebral tumors, receiving a large portion of their blood supply from the external carotid, are nearly always meningiomas, the notable exceptions are those tumors originating about the sella turcica, the dorsum sellae, and posterior fossa Convexity meningiomas cause hypertrophy of the middle meningeal artery and frequently some of the branches of the superficial temporal artery that will penetrate the calvarium to help supply the tumor

Since the dura in the region of the cribriform plate and anterior falx are supplied by branches of the ophthalmic artery, internal carotid contrast injec tions will be necessary to outline these lesions Similarly, dural branches arising from the internal carotid artery, as it leaves the carotid canal, supply meningi omas about the free margins of the tentorium and the region of the dorsum sellae

The definition of vessels, which result when contrast material is delivered undiluted, selectively, by catheter, enables one to evaluate the small vessel details of tumors

Meningioma vessels branch in an irregular fashion, pursue a tortuous course but have a lumen of uniform caliber 'Staining may occur but is usually late in the series In our case of malignant meningioma, numerous areas of puddling of contrast were present during the early arterial phase In addition, the lumen of the small arterioles were much more irregular and showed alter nate areas of widening and relative narrowing (Fig 2)

Arteriovenous malformations of the soft tissues of the head and neck derive



Fig 5 Selective external carotid angiography in a 33 year-old male who had had a tonsillectomy in 1960 for repeated sore throats After a two year interval his sore throats recurred and a repeat tonsillectomy was undertaken in January 1963 A large tonsillar mass was encountered which proved to be a neurilemmoma Selective external carotid angiography revealed posterior displacement of the external carotid artery by the tumor mass (← and hypertrophy of the ascending pharyngeal branch (↔) with tumor stain in the mass



Fig 6 Subtraction film of a selective external carotid angiogram in a 56 year-old male with a six month history of pain in the right side of his head in the posterior frontal and parietal areas He developed paralysis of the right VI VII IX X XI and XII cranial nerves The pathologic diagnosis was epidermoid carcinoma of the nasopharynx Selective external carotid angiography revealed displacement of the external carotid artery anteriorly (←) and the internal maxillary artery inferiorly (↔)

much or all of their blood supply from the external carotid artery Preoperative mapping of the arterial supply of these malformations with selective external carotid angiography is an important adjunct to their management

The angiographic diagnosis of tumors of the soft tissues of the head and neck is based upon two factors the vascularity of the tumor which may include tumor vessels and the displacement of normal vessels by the mass of tumor For example carotid body tumors are usually quite vascular and occur in a typical location at the common carotid artery bifurcation They tend to bleed profusely at surgery Most reports indicate they derive their blood supply from the common carotid artery (IDBOHRN 1951) In the past, when excessive bleeding was encountered at surgery the common carotid artery was sacrificed Sudden ligation of the common carotid artery carries with it a 30 % incidence of mortality and as high as 80 % morbidity

Preoperative selective external carotid, internal carotid, vertebral, thyrocervical trunk, and costocervical trunk angiography can be performed at two sittings utilizing a common carotid puncture and an axillary artery puncture by catheter technique It is important to know whether any of these vessels make contributions to the tumor blood supply The only method of being absolutely certain is with selective catheter angiography An example of the importance of this evaluation is presented (Figs 3 and 4) In our case, the only vessel which did not contribute to the tumor was the internal carotid artery

Tumors of the pharynx can displace branches of the external carotid and may derive their blood supply from these branches The ascending pharyngeal artery supplies the pharynx and soft palate and will enlarge when tumors occur in this area Tumor 'staining' may also be demonstrable (Fig 5)

These angiographic changes are also encountered in tumors of the nasopharynx (Fig 6), tongue, floor of the mouth, and salivary glands

Another application of selective carotid angiography in tumors of the soft tissues of the head and neck is the placement of the polyethylene catheter for optimal perfusion therapy with drugs Selective perfusion will spare the brain in these tumors and, conversely, brain tumors may be perfused by placing the catheter in the internal carotid artery and sparing the skin and soft tissues of the head and neck If the superior thyroid artery is to be included in an external carotid perfusion, the catheter had best be passed in a retrograde fashion via a surgically exposed branch of the superficial temporal, since the origin of the superior thyroid artery is very near the orifice of the external carotid artery The catheter has remained in place as long as 14 days Care must be taken to prevent vascular thrombosis or infection Surprisingly these catheters can be removed at the conclusion of perfusion therapy with no more difficulty than after being in place 1 to 2 hours

Finally, selective external carotid angiography is of value in demonstrating collateral circulation from the external carotid to the internal carotid and vertebral arteries Collateral circulation through the ophthalmic occurs via the external carotid to external and internal maxillary, to the nasal, lacrimal, and supraorbital branches of the ophthalmic artery, and has been well documented (MARX 1949) Other collateral routes are external carotid artery to the descending branch of the occipital artery to vertebral artery (RICHTER 1958), ascending pharyngeal to ascending cervical to vertebral, middle meningeal to rete mirabile to leptomeningeal arteries, and internal maxillary to meningeal arteries from the carotid siphon

Final positioning of the catheter depends upon the abnormality under investigation For meningiomas, it is desirable to have the tip of the catheter above the lingual artery, since the blood supply to the tongue constitutes a

major source of loss of injected contrast material In the investigation of collateral flow from the external carotid artery, it is also desirable to have the catheter tip above the lingual artery Tumors of the soft tissues of the head and neck may require injections at the origin of the external carotid artery or into specific branches It is difficult and probably not advisable to advance the catheter above the level of the posterior auricular artery because of the decreasing diameter of the external carotid artery

SUMMARY

Selective external carotid angiography by the catheter technic enables a safe study of the external carotid arterial circulation in greater detail than has been possible in the past The catheter can be manipulated in the artery to selectively demonstrate segments of the external carotid arterial circulation The procedure has therapeutic implications for the infusion of chemotherapeutic agents The technic and indications for external carotid angiography are described and illustrated

ZUSAMMENFASSUNG

Die selektive Angiographie der Arteria carotis externa mittels Kathetertechnik ermoglicht ein Studium ohne Risiko der Zirkulation der Halsarterie in genauerem Detail als bisher Bei Manipulierung des Katheters in der Arterie kann der arteriellen Zirkulation von einzelnen Segmenten der Carotis externa dargestellt werden Das Verfahren ist auch von Bedeutung bei der Infusion von chemotherapeutischen Mitteln Die Technik wird beschrieben und die Indikationen fur ihre Anwendung angegeben Einige beleuchtenden Untersuchungen werden beschrieben

RÉSUMÉ

L angiographie carotidienne externe sélective par cathétérisme permet d étudier sans danger la circulation carotidienne externe avec plus de détail qu il n était possible auparavant On peut manoevrer le cathéter dans l artere pour mettre en évidence électivement des parties de la circulation carotidienne externe Cette technique a des applications pour la perfusion d agents chimiothérapeutiques Les auteurs décrivent la technique et les indications de l angiographie carotidienne externe et en présentent des exemples

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FROM THE DEPARTMENT OF DIAGNOSTIC RADIOLOGY (DIRECTOR PROF F KNUTSSON) THE UNIVERSITY HOSPITAL UPSALA SWEDEN

ANGIOGRAPHY IN SENILE CEREBRAL ATROPHY

by

K BERGSTROM and H LODIN

An avascular zone between the surface of the brain and the calotte at angiography in adults is considered an indication of extracerebral haematoma The different types of extracerebral haematomas i e acute and chronic subdural haematomas and epidural haematomas may also generally be distinguished angiographically (NORMAN 1956 CRONQVIST & KOHLER 1963) There are however conditions, such as senile cerebral atrophy in which the angiographic appearances so much resemble those of an acute subdural haematoma as to make the differential diagnosis difficult or impossible

A fluid filled space between the brain surface and the calvaria in advanced cerebral atrophy results from a volumetric reduction of the brain and at angiography produces an avascular zone This diagnostic alternative to subdural haematoma has not been given much attention in the literature GLONING & KLAUSBERGER (1956) mentioned that in advanced cerebral atrophy an avascular zone appeared under the calotte and that this zone is evenly distributed over the whole cerebral surface while in subdural haematoma it is limited to a part of the hemisphere The pericallosal artery may be situated in the midline in both conditions BILLET (1959) also described an avascular

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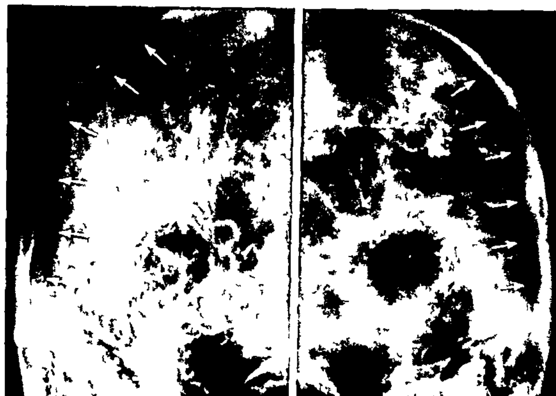


Fig. 1. Case 1. Bilateral avascular zone towards the bregma; irregular brain surface.

zone over the whole hemisphere in four probable cases of cerebral atrophy, the same observation was made by TAVERAS & POSER (1959) in children, and by ENGESET & KRISTIANSEN (1960). CRONQVIST & TROUPP (1963) published a case of local cortical atrophy, after a cerebral 'accident', with an avascular zone limited to a part of the brain surface that was irregular. This irregularity has not been previously reported in subdural haematoma and could most probably be pathognomonic of local cortical atrophy. CRONQVIST also mentioned that TAVERAS' as well as ENGESET's reproductions suggest that an irregular outline of the brain also probably existed in their cases.

The present investigation was performed to determine the possibilities of the angiographic differential diagnosis between senile cerebral atrophy and acute subdural haematoma and is based upon a re-examination of all carotid angiographies carried out in 115 patients over 70 years of age during the period 1952—1963, the oldest patient was 88. Thirty-two of the patients had been operated upon following diagnoses of extracerebral haematoma; haematomas were found in 29 and effusion and cerebral atrophy in 3 of these patients; senile cerebral atrophy was probably also present in a patient in the remaining part of the material (see Case 4).

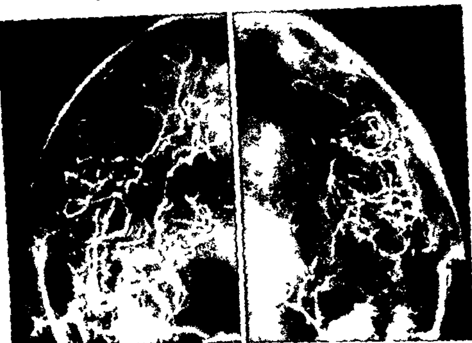


Fig 2 Case 2 Avascular zone 0 5 cm wide on the right side and 1 cm on the left in the frontal region irregular spread from the base to the bregma on the right side

Case reports

Case 1 Man aged 84 years unconscious after a traffic accident No history of previous cerebral symptoms Contusion at the back of the head no positive nerve signs and roentgen examination negative The following day the Babinski sign was positive on the left side but some days later was negative on both sides During the first days he was semi unconscious but some days later his condition grew worse

Bilateral carotid angiography was performed seven days after admission (Fig 1) A bilateral avascular zone up to 1 cm in width and most marked in the frontal region lay between the brain surface and the calotte The brain surface was irregular the pericallosal artery was not obviously displaced

Transparent fluid bilaterally on trepanation no haematoma increased distance between the dura and brain surface

The patient died some hours after operation and autopsy disclosed senile cerebral atrophy no acute cerebral damage

Case 2 Woman aged 88 with an injury to the back of the head and increasing loss of consciousness no history of previous cerebral symptoms no evidence of fracture

Bilateral carotid angiography was performed four days after the trauma (Fig 2) An avascular zone 1 cm wide on the left and 0 5 cm wide on the right side lay between the brain surface

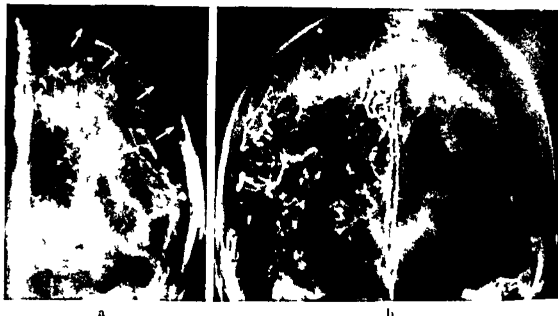


Fig. 3. a) Case 3. Localized avascular zone in parietal region 0.5 cm wide, regular brain surface, the internal cerebral vein is not displaced. b) Case 4. Avascular zone 0.5 cm wide, regularly distributed from the base towards the bregma, smooth brain surface, the pericallosal artery is curved to the right.

and the calotte in the frontal region, the pericallosal artery was not displaced. The brain surface was regular.

Transparent fluid bilaterally on trepanation, but no haematoma, somewhat increased distance between the dura and the brain surface.

The patient recovered and was discharged in two weeks.

Case 3. Man, aged 72, with an injury to the back of head causing giddiness and headache. Previous history negative, no positive nerve signs but the right occipital bone was fractured.

Right carotid angiography was performed seven days after the trauma. No interposition between the brain surface and the calotte, the pericallosal artery was tortuous but not definitely displaced.

Left carotid angiography 13 days after the trauma (Fig. 3a) disclosed a 0.5 cm wide avascular zone between the calvaria and the regular brain surface in the parietal region. The pericallosal artery was markedly tortuous but not obviously displaced.

Transparent fluid was on left side trepanation present, no haematoma, somewhat increased distance between the dura and brain surface.

Postoperative course without complications.

Case 4. Man, aged 76, unconscious following injury to the left temporal region. Three years history of parkinsonism but no other symptoms, fracture through the left parietotemporal region, no nerve changes.

Trepanation was not performed. The patient died nine days following examination after gradually increasing unconsciousness. Autopsy was refused.

Carotid angiography was performed two days after the trauma (Fig. 3b). An avascular zone

0 5 cm wide was seen to be regularly distributed between the entire calvaria and the brain surface on the right side no changes on the left side The brain surface was not abnormal the pericallosal artery was curved to the right no evidence of arteriosclerosis

Bilateraly angiography was performed in all the four cases The avascular zone was bilateral in two cases (Cases 1 and 2) and unilateral in two cases (Cases 3 and 4) The brain surface was regular in three cases (Cases 2 3 and 4) and irregular in Case 1 The avascular zone was fairly regularly distributed from the base to the bregma in two cases (Cases 2 and 4) but not in the other two (Cases 1 and 3) The pericallosal artery was not definitely displaced from the midline in three cases (Cases 1, 2, and 3) but in Case 4 which had a unilateral avascular zone it curved towards the same side

Senile cerebral atrophy and absence of haematomas were verified by operation and autopsy in Case 1 and by operation in Cases 2 and 3 No operation or autopsy was performed in Case 4 but although the avascular zone was unilateral and the pericallosal artery was curved towards the same side, cerebral atrophy was considered probable

Of the 115 patients examined who were over 70, 33 had an interposition between the brain surface and the calvaria, in four due to atrophy, the atrophy was bilateral in two patients The histories in the patients with atrophy gave no indication of cerebral changes The incidence of atrophy may in reality be somewhat greater than is apparent because it may have been present in some of the haematoma patients

The frequency of angiographic examination in the oldest *age groups in the* material successively increases because of the more active attitude to geriatrics and therefore senile brain atrophy becomes of greater importance as a diagnostic alternative to the acute subdural haematoma GLONING & KLAUSBERGER were of the opinion that in typical cerebral atrophy, contrary to subdural haematoma the avascular zone is evenly spread over the whole brain surface This was not so in the present Cases 1 *2 and 3 however* They also emphasized that in atrophy the pericallosal artery is always situated in the midline It would appear that this is not necessarily the case CRONQVIST & TROUPP insisted that in acute subdural haematoma the brain surface is always regular This again does not appear to be entirely true The degree of regularity of the brain surface varied in the cerebral atrophy cases of the present material and a case with a somewhat *irregular surface* demonstrated at angiography was found at operation to be one of subdural haematoma The appearances may be confused and reversed in haematomas that are not quite recent and not yet of the bi convex form of the chronic haematoma, and they may also be present in an acute haematoma combined with an irregular brain surface caused by atrophy

Conclusion

Senile cerebral atrophy and acute subdural haematoma may be differentiated angiographically when an avascular zone is unilateral, since in the former no increase in pressure exists and the pericallosal artery therefore is situated in the midline or possibly displaced over to the atrophic side. Such a differentiation cannot be made if the zones are bilateral. Cerebral atrophy is, however, indicated if the zones are of different sizes and the pericallosal artery is situated in the midline, as in our Case 2.

SUMMARY

The angiographic appearances in four cases of senile brain atrophy, three of which were verified operatively, are described. The differential diagnosis of acute subdural *haematoma* is discussed.

ZUSAMMENFASSUNG

Das angiographische Bild in vier Fällen von seniler Gehirnatrophie wird beschrieben, drei von diesen Fällen wurden operativ verifiziert. Die Differentialdiagnose gegenüber dem akuten Subduralhämatom wird diskutiert.

RÉSUMÉ

Description des images angiographiques dans quatre cas d'atrophie cérébrale sénile dont trois ont été vérifiés par opération. Discussion du diagnostic différentiel avec l'hématome sous-dural aigu.

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FROM THE DEPARTMENT OF DIAGNOSTIC RADIOLOGY, CHILDREN'S CLINIC, KAROLINSKA SJUKHUSET, STOCKHOLM, SWEDEN

PNEUMOMEDIASTINUM AND PNEUMOTHORAX IN THE NEWBORN

by

ULF RUDHE and M. B. OZONOFF

Recent therapeutic advances have done much to reduce peri-natal infant mortality. This applies especially to the infectious diseases and those due to mechanical respiratory embarrassment, such as diaphragmatic hernia and pneumothorax. Roentgenologic investigation in neonatal respiratory distress has been accepted as the best one of the single diagnostic methods available, and a large amount of experience has been accumulated. The result of this has been the recognition that pneumomediastinum and pneumothorax can no longer be regarded as uncommon entities of obscure etiologic origin. As many authors (EVANS & SMALLDON 1950, LYON 1963, HAN et coll. 1963) have discussed the probable pathogenesis, this will now not be further considered except to emphasize that the experience of the present authors has been similar to that of others.

Most of the cases were referred to us due to respiratory distress in the neonatal period. This report will deal with the specific aspects of roentgen techniques and the use of certain principles in distinguishing pneumomediastinum from pneumothorax in the newborn.

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Conclusion

Senile cerebral atrophy and acute subdural haematoma may be differentiated angiographically when an avascular zone is unilateral, since in the former no increase in pressure exists and the pericallosal artery therefore is situated in the midline or possibly displaced over to the atrophic side. Such a differentiation cannot be made if the zones are bilateral. Cerebral atrophy is, however, indicated if the zones are of different sizes and the pericallosal artery is situated in the midline, as in our Case 2.

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Fig 1 Left pneumothorax in a 1 day old male infant Air surrounds the lung most of the anterior air lying superior to the heart the subpulmonary location (arrow) is also evident

In summary then pneumothorax alone was most frequently encountered (30/70) pneumothorax and pneumomediastinum next frequently (25/70) and isolated pneumomedistinum was seen least often (15/70)

Radiologic technique For all the infants except one, both a p and lateral films of the chest were obtained with the subject in recumbent position Oblique films when obtained were produced by rotating the patient from the supine position these films may therefore be said to represent left, or right, posterior oblique projections All these views could be achieved with the infant in the nursery incubator If supine prone or lateral decubitus horizontal projections were desired the baby had to be removed from the incubator and placed on the radiographic table The exposure time was usually 0 004 seconds when the examinations were made in the roentgen department while films produced by the mobile unit were taken at 0 02 seconds

A desire to avoid disturbing these infants who were often in a precarious clinical state made the use of the erect position undesirable, as it was felt that the removal of the infant from his environment in the incubator, and the associated handling would be more of a disadvantage than a help It cannot be denied however that the detection of a pneumothorax might have been easier if the erect position could have been used we believe however that the disadvantage can be largely compensated for by employing the various

Description and analysis of the case material. All the cases, with a few exceptions, were seen after delivery in the obstetric division of the hospital, only a few cases had been transferred from other hospitals. Seventy cases of pneumomediastinum and/or pneumothorax were found by reviewing approximately 1 800 abnormal newborn chest films obtained during the 14 year period under analysis (1951—1964). The number of babies born at the hospital during this interval was approximately 26 500, thus giving a rough incidence of one case per 380 births, or 0.26 %.

Post mortem examination in several cases revealed interstitial emphysema as well as pneumothorax or pneumomediastinum. Hyaline membrane disease could also be demonstrated pathologically in two cases. Roentgenologically, this entity was probably present in two others, and 12 had grossly abnormal aeration of the lungs (e. g. aspiration atelectasis, lobar atelectasis, pneumonia).

Thirty nine of the cases were first seen on the day of birth and 19 on the second day of life. In all, 65 of the 70 infants in this analysis were 3 days old, or younger, when the diagnosis was made.

Anteroposterior and lateral films of the chest were obtained for the basic examination, and in the majority of cases (50) oblique views as well, 18 cases were examined by further special projections.

Pneumothorax was found in 55 cases. Thirty of these 55 had pneumothorax alone, and 25 had an associated pneumomediastinum. The intrapleural air was unilateral in about three fourths of the cases (41/55) and bilateral in the rest. There were almost twice as many right pneumothoraces as left ones but the significance of this cannot be ascertained for a case material of this size. Mediastinal shift was present in 19 of the 41 unilateral pneumothoraces and 7 of the 14 bilateral pneumothoraces. Subcutaneous emphysema was not observed with pneumothorax alone.

Pneumomediastinum was present in 40 of the 70 cases, only 15 of which had no associated pneumothorax, i. e. well over half of all the cases with pneumomediastinum had pneumothorax as well. Mediastinal displacement was evident in only one case of isolated pneumomediastinum. Subcutaneous emphysema was present only in the neck, and its occurrence was uncommon (7 of 40 cases).

Pneumomediastinum and pneumothorax thus co-existed in a large number of cases (25 of the total of 70). The presence of both entities was noted in somewhat less than half of all pneumothorax cases (25/55) and in five eighths of all pneumomediastinum cases (25/40).

Males were more frequently affected than females, 45 of the 70 cases being male and only 25 female. There is no apparent reason for this, but other reports (JOSEPH et coll. 1964, CHASLER 1964) in infants and adults with spontaneous pneumothorax give a similar male preponderance.

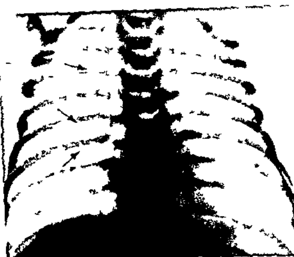


Fig 3 Pneumomediastinum and left pneumothorax in a 2 day-old male infant The mediastinal pleura (arrows) is displaced by the pressure of the air in the mediastinum junction of right transverse fissure and parietal pleura thymus slightly elevated The pneumothorax lies in a left subpulmonary position

displaced posteriorly In the oblique views a combined lateral and subpulmonary position was most common Some of the air seemed to have migrated forward to this subpulmonary position but a purely lateral accumulation was frequently evident

The pneumothorax was best demonstrated by rotating the patient to the posterior oblique position that corresponded with the pathologic side The opposite oblique view, with the affected side raised usually failed to reveal the pneumothorax unless marked mediastinal shift was *present*

An observation of some importance was that the a p view disclosed no changes in almost one sixth of the cases (9/55) of these 9 cases the oblique view showed the air accumulation well in 6 cases which indicates its importance Fig 2) In only 2 cases was the oblique view normal when the pneumothorax was evident in other projections

The horizontal views were occasionally helpful but were usually not necessary for the establishment of a diagnosis When the patient was changed from one lateral decubitus position to the other or from supine to prone it was noted that most of the air shifted position so as to remain in its expected most superior position Not all the air moved however due no doubt to mechanical factors impeding its complete displacement It was also observed that with the patient supine the air accumulated anteriorly along the superior mediastinum which is not the highest position this is again probably related to a resistance to any posterior displacement of the heart

Subcutaneous emphysema was never present with pneumothorax alone

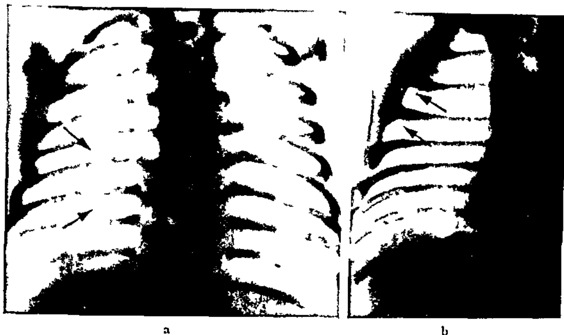


Fig. 2. Right pneumothorax in a 2 day old male infant. a) A-p view. Air trapped medially adjacent to the heart (arrows) but no pleural outline for intrapleural or intramediastinal localization is evident. b) Right posterior oblique view. Lateral border of the lung confirms the pneumothorax (arrows); air is still trapped medially.

projections to be described below. For the same reasons we limited the use of the various horizontal projections to cases that presented a special diagnostic problem. Serial examinations were often of value.

Roentgen findings in pneumothorax and pneumomediastinum

Pneumothorax. The slight male preponderance, a tendency towards unilateral *location and frequent association with pneumomediastinum have already* been mentioned. Definite pulmonary interstitial perivascular air infiltration, occasionally demonstrated clinically, could rarely be seen radiologically, but an apparent rigidity of the lung was obvious, with resistance to collapse and consequent mediastinal displacement. The latter was often present even with bilateral pneumothorax.

Definite areas of preference for the accumulation of the free air were evident in the various projections. In the a. p. (supine) view the air was seen to border the lung laterally in over half of the number of cases and lay in a subpulmonary position interposed between lung base and diaphragm in a quarter of the cases. In the lateral view (Fig. 1), air was noted anteriorly as well, predominantly superior to the heart, implying that the heart offered resistance to being

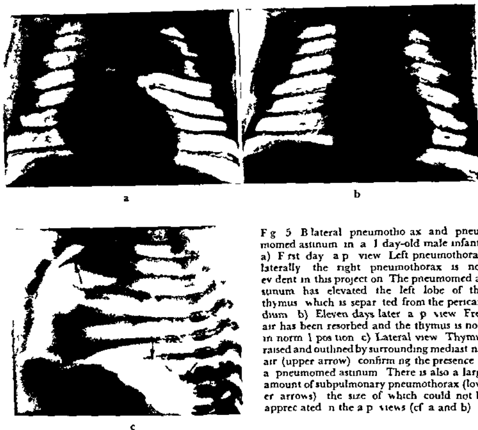


Fig 5 Bilateral pneumothorax and pneumomediastinum in a 1 day-old male infant a) First day a p view Left pneumothorax laterally the right pneumothorax is not evident in this projection The pneumomediastinum has elevated the left lobe of the thymus which is separated from the pericardium b) Eleven days later a p view Free air has been resorbed and the thymus is now in normal position c) Lateral view Thymus raised and outlined by surrounding mediastinal air (upper arrow) confirming the presence of a pneumomediastinum There is also a large amount of subpulmonary pneumothorax (lower arrows) the size of which could not be appreciated in the a p views (cf a and b)

location was the same as that for pneumothorax Only in pneumomediastinum (with one exception) however was the thymus raised or outlined by the air and this finding is probably diagnostic for pneumomediastinum Outlining of both the anterior and inferior surfaces of the thymus (Fig 5c) was noted in 16 cases in 11 cases only the lower surface was outlined or raising of the thymus was seen Displacement of the thymus was present in a total of two thirds of the cases

The oblique views generally confirmed the findings in the a p views with central air accumulations pleural lines and outlined thymic lobes again being the salient abnormalities (Fig 6) Moreover as in pneumothorax displaced mediastinal pleurae were demonstrated in 7 cases only in the oblique view and were not apparent in the a p view Only in one case was the oblique projection completely normal

Horizontal views were not often necessary but were occasionally helpful

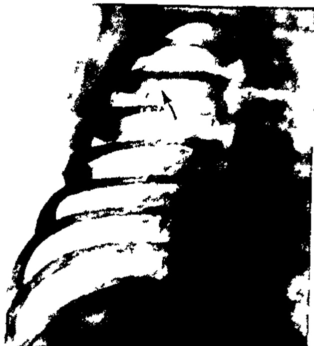


Fig 4 Bilateral pneumothorax and pneumomediastinum in a 1 day old male infant Air caps the apex of the lung the thymus has been raised by pressure of air in the mediastinum (arrow) the lateral border of which is faintly demarcated

Pneumomediastinum While there was a frequent association of pneumothorax with pneumomediastinum, progression from one to the other was rarely encountered in this material There was no evidence that this did not occur, however

Accumulation of air was seen centrally in the a p view There was no preference between a predominantly left, right, bilateral, or central (over the spine) location, and no correlation was observed between the location of the mediastinal air and the lateral position of any associated pneumothorax

The mediastinal pleura was often represented as a line demarcating the lateral border of the mediastinal air accumulation (Fig 3), and this has been found to be an important sign by which pneumomediastinum may be differentiated from a medially located pneumothorax This linear density is produced by the mediastinal pleura which has been displaced by the pressure of the mediastinal air and is viewed tangentially It was never observed with pneumothorax but was present in 17 of the 40 cases of pneumomediastinum

Streaky paramediastinal air deposits were occasionally present Of more importance was an elevation of the thymic lobes so that they were lifted free of the heart Air could often lay below them, sometimes demarcated by the mediastinal pleura (Fig 4, and Fig 5, a and b)

The lateral view showed the air to accumulate mainly in the superior mediastinum, although some air was often seen also anterior to the heart, the

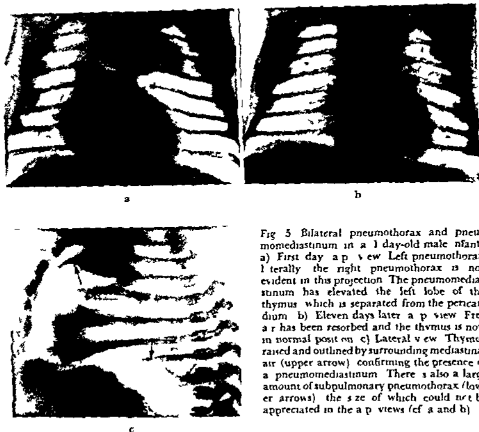


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The oblique views generally confirmed the findings in the a p views, with central air accumulations pleural lines and outlined thymic lobes again being the salient abnormalities (Fig 6) Moreover as in pneumothorax displaced mediastinal pleurae were demonstrated in 7 cases only in the oblique view and were not apparent in the a p view Only in one case was the oblique projection completely normal

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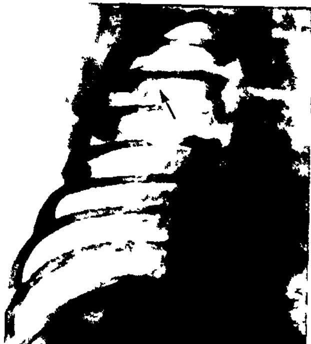


Fig. 4. Bilateral pneumothorax and pneumomediastinum in a 1 day old male infant. Air caps the apex of the lung; the thymus has been raised by pressure of air in the mediastinum (arrow), the lateral border of which is faintly demarcated.

Pneumomediastinum. While there was a frequent association of pneumothorax with pneumomediastinum, progression from one to the other was rarely encountered in this material. There was no evidence that this did not occur, however.

Accumulation of air was seen centrally in the a. p. view. There was no preference between a predominantly left, right, bilateral, or central (over the spine) location, and no correlation was observed between the location of the mediastinal air and the lateral position of any associated pneumothorax.

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Streaky paramediastinal air deposits were occasionally present. Of more importance was an elevation of the thymic lobes so that they were lifted free of the heart. Air could often lay below them, sometimes demarcated by the mediastinal pleura (Fig. 4, and Fig. 5, a and b).

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2 In the lateral views anterior or subpulmonary air was evident in about two-fifths of the cases but never in cases of pneumomediastinum

3 In the oblique views, lateral or subpulmonary air was never seen in pneumomediastinum

4 Shift of the major portion of air occurred when the patient was moved from the supine to prone position or from the left decubitus to the right decubitus position

5 Mediastinal displacement was common

6 Subcutaneous emphysema was not present

Pneumomediastinum

1 In the a p view, central air with or without a demarcating mediastinal pleura and outlined or raised thymus are diagnostic and these features were not seen in pneumothorax

2 In the lateral view the thymus was outlined or raised in two thirds o cases

3 In the oblique view the mediastinal pleura and thymus were outlined

4 No shift in the location of air accumulations was evident when the pa tient was moved from the supine to the prone or from the right decubitus to the left decubitus position

5 Medial displacement if ever present is rare

6 Subcutaneous emphysema occurs but is uncommon in pneumomedias tinum and is never present in pneumothorax

Pneumothorax and pneumomediastinum in co existence

The signs described before are applicable to each component even if bot co-exist No significant differences were noted due to the effect of one entit on the other

Discussion

The etiologic origin of pneumomediastinum and pneumothorax is n doubt related to pressure changes taking place with the early extra uterin respiratory movements KARLBERG et coll (1962) have reported a marked fa in intrathoracic pressure with a total change of 40 to 100 cm H O during th



Fig. 6. Value of oblique projections. The outline of the greatly distended pleura (arrow) and the elevation of the thymus from the heart are often most easily demonstrated in this projection. a) Pneumomediastinum in a 1 day old male infant. b) Bilateral pneumothorax and pneumomediastinum in a 1 day old male infant.

An interesting and predictable finding was the absence of displacement of the air when the patient was moved from one lateral decubitus position to the other, or from the supine to the prone. The latter maneuver may at times be important in distinguishing pneumomediastinum from pneumothorax.

Subcutaneous emphysema was present in only 7 cases. This is somewhat surprising, as it was often obvious from its marked distension that the mediastinum was under considerable pressure. Anatomical factors evidently prevent subcutaneous relief of the pressure and render intervention important. Mediastinal displacement was present with pure pneumomediastinum in only one case, in which a latent pneumothorax may have been present.

Radiologic differentiation between pneumothorax and pneumomediastinum

It is necessary for therapeutic reasons to determine to which compartment the abnormal air accumulation is limited. This is often difficult, especially in the frequent cases in which the a. p. view is normal and the lateral views reveal only an anterior accumulation. It has been shown that both pneumothorax and pneumomediastinum, as well as certain other conditions, may produce this appearance. The best course is to obtain posterior oblique views, as has been mentioned. Only rarely, then, will it be necessary to take the infant out of the incubator to obtain horizontal views. The following are the salient features of the two entities.

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Fig. 7. Bilateral pneumothorax and *pneumomediastinum in a 1 day old* male infant. Mediastinal pleurae well shown (arrows); the diffuse reticular structure of the lungs suggests the presence of pulmonary interstitial emphysema.

first breath. With such a marked dynamic alteration taking place, it is obvious that an alveolar weakness, as has been postulated in prematurity, or alveolar distention secondary to aspiration and valvular bronchiolar obstruction, may cause rupture of the alveolus and entrance of air into the perivascular space.

Although interstitial emphysema in several instances could be demonstrated pathologically, no intrapulmonary perivascular air accumulations could be positively identified roentgenologically. Streaky or honeycomb appearances were sometimes evident in the films, however (Fig. 7). Another observation which suggested the presence of interstitial air was the apparent non-compliance of the lung which produced the frequently observed failure of the lung to collapse, with consequent mediastinal displacement. While there is no reason to doubt the experimental observation (MACKLIN 1939, OVENFORS 1964) that alveolar distention and rupture, with perivascular tracking of the air into the mediastinum, is the usual pathogenesis, this sequence of events, or the subsequent evolution of pneumomediastinum into pneumothorax, was rarely demonstrated.

It is apparent from the number of cases of pneumothorax and pneumomediastinum discovered in this evaluation of distressed infants that the condition is not rare, as is usually held. The present series gives an approximate incidence of 70 in a total of 26 500 cases or 0.26 % of the number of newborns during the 14 years under review. This conforms generally with an incidence of pneumothorax in full term births amounting to 1 to 2 %, and in prematures amounting to 0.7 % as reported by LUBCHENCO (1959) in 27 cases of spontaneous pneumothorax over a 9 year period. HARRIS & STEINBERG (1954)

gave an incidence of only 0 07 % in over 8 000 newborn infants and this would seem to be somewhat low

The differential diagnosis of pneumothorax and pneumomediastinum from other conditions is not difficult Centrally or anteriorly located air may be present in loculated pneumopericardium, herniated lung, herniated mediastinal pleura due to tension pneumothorax or with an air dilated esophagus as well as in pneumomediastinum Examples of all of these with the exception of the first, have been encountered and the correct diagnosis is usually made The differentiation of pneumothorax from pneumomediastinum is generally the hardest problem

The difficulty of differentiating these two entities arises mainly from the frequency with which the a p view of the thorax appears normal or equivocal The only clue then to the presence of abnormal free air is an anterior accumulation in the lateral view this is however non specific as it will appear in this location in either condition The signs enumerated should be helpful in separating the two lesions and there should be no hesitation in obtaining oblique views The posterior oblique views occasioned only slightly more handling of the infant and were found to be generally superior to the a p views in detecting small pneumothoraces no doubt due to the fact that in this position the displaced pleura can be projected tangentially

It is obvious that if pneumomediastinum can proceed to pneumothorax there should be a stage when both are present It appears more likely that a pneumomediastinum should be associated with a pneumothorax than that the pneumothorax should be isolated Both entities were present in 25 ca es of the series but in 30 cases pneumothorax alone was demonstrated This seems to indicate that many small air accumulations must go undetected even by the multiple examinations that have been described Thus when an apparently isolated pneumothorax is observed this should constitute a cause for further search for an obscured pneumomediastinum the thoroughness of the investigation having to depend on the clinical state of the infant A mall, latent pneumomediastinum while not of great clinical significance, may be an indication of a continuous air leak if demonstrated late in a sequence of examinations

Conclusions

The investigation has revealed that pneumothora is characterized by a lateral subpulmonary and anterior free accumulation of air often mediastinal displacement and the absence of subcutaneous emphysema Centrally and anteriorly located free air with raising or outlining of the thymic lobes and frequent delineation of the distended mediastinal pleura on the other hand



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appeared to be typical signs of pneumomediastinum. Subcutaneous emphysema was occasionally present.

A.-p. and lateral views are necessary for the diagnosis, and additional oblique projections were often found to be essential for a definite localization. All these views may be obtained without removing the infant from his nursery incubator. The frequent co-existence of pneumothorax and pneumomediastinum is to be expected on theoretical grounds and was often evident in the series. Efforts must be made fully to determine the location of the air accumulation in order to effect appropriate therapy.

Acknowledgement

This investigation was carried out during the tenure by M. B. O. of a James Picker Foundation Fellowship in Radiological Research. Financial support by a grant from the Swedish National Association against Heart and Chest Diseases is also gratefully acknowledged.

SUMMARY

The roentgen findings in a series of 70 newborn infants with pneumomediastinum and/or pneumothorax are described and analyzed. An account of the radiologic technique is given and the principles considered to be of particular value in distinguishing between pneumomediastinum and pneumothorax are discussed.

ZUSAMMENFASSUNG

Die Röntgenbefunde in einer Serie von 70 Neugeborenen mit Pneumomediastinum und/oder Pneumothorax werden beschrieben und analysiert. Es wird hervorgehoben, dass die Untersuchungstechnik von besonderer Bedeutung ist. Methoden, die geeignet sind, eine Differenzialdiagnose festzustellen, werden angegeben.

RÉSUMÉ

Les auteurs analysent et décrivent les signes radiologiques trouvés sur une série de 70 nouveau-nés atteints de pneumomédiastin et/ou de pneumothorax. Ils indiquent les principes de la technique radiologique qui sont considérés comme les meilleurs pour le diagnostic différentiel entre pneumomédiastin et pneumothorax.

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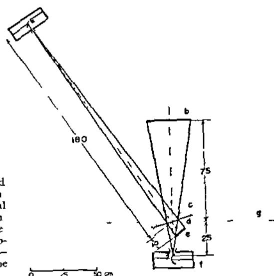


Fig 1 Arrangement of roentgen tubes and films for obtaining conventional and enlargement roentgenograms in an identical phase a — tube and b — film for conventional roentgenography c — tube and d — film for enlargement roentgenography e — radiographic table f — supplementary table g — subject to be examined

with twofold magnification roentgenography have now become discernible (TAKAHASHI 1960 1962)

Attempts have been made in recent years to study experimentally the vascularization of tumours by angiography (LAGERGREN et coll 1960 1961 1962 MARGULIS et coll 1961) TAKARO et coll (1962) and TAKARO & SCOTT (1964) recently carried out angiography of the normal leg and the lung by the two fold magnification technique with a 0 3 mm focus tube The present authors also conducted similar studies on the living body at fourfold magnification and some of the results were reported at the 10th Congress of Radiology in Montreal in 1962 Further developments in our angiographic technique will now be described

1 Roentgen tube with very small focus The tube is similar to an ordinary rotating anode tube The focusing cap however is so constructed that when positively charged the current emitted from the special heating filament converges due to bias phenomena then the focal spot produced on the anode becomes so small that it cannot be measured accurately by the pin hole camera method A test marker consisting of parallel tungsten wires 25 μ in diameter and arranged at intervals of 25 μ is placed at a distance of 20 cm from the focal spot perpendicular to the central beam The film is placed perpendicular to the central beam at a distance of 80 cm from the test piece Since the test marker is completely resolved in the roentgenogram (TAKAHASHI & YOSHIDA 1957) the size of the focal spot cannot be more than 50 μ (TAKAHASHI et coll 1955)

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ANGIOGRAPHY AT FOURFOLD MAGNIFICATION WITH SPECIAL REFERENCE TO THE EXAMINATION OF TUMOURS

by

S TAKAHASHI, S SAKUMA, M KANEKO and S KOGA

Roentgenography of high magnification requires a roentgen tube of extremely fine focus The smallest tube at present available has a focal spot of 0 3 mm, it was first described by BURGER et coll (1946) Although numerous clinical studies have been conducted with enlargement roentgenography it seems that no new information has been forthcoming that is not obtainable by ordinary roentgenography (BUCHNER 1954, TAKAHASHI & YOSHIDA 1957) Roentgenograms of greater magnification ratio can however be obtained by a further reduction in size of the focal spot, tubes with a focus of less than 0 3 mm have been prepared, and attempts to utilize them in medicine have been made by ADEHOLD & SEIFERT (1954) and TAKAHASHI et coll (1958) Enlargements of from 11 to 15 times have become possible to achieve, and this type of enlargement roentgenography is valuable in examinations both with and without contrast media (TAKAHASHI et coll 1960) Details not possible to demonstrate

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Fig 3 Angiogram obtained by the fourfold enlargement technique in the arterial phase Number of vessels in tumour bed increased as compared with the conventional angiogram (shown as an inset bottom left test marker at right margin of tumour black arrow) Faintly outlined vessels are seen to radiate from the hilum (white arrow) to the tumour and these could be discerned only in the enlargement angiogram Test marker at the base of the tumour wires of 40 μ in diameter were resolved

the styloid process of the right radius of a male aged 71, were made with the unit (Fig 2) The site was anesthetized locally with xylocaine an injection needle was introduced into the brachial artery and 100 ml Urografin 76 % were injected Serial angiography was performed immediately after the injection at five intervals of 3 to 4 seconds The data for enlargement angiography were 115 kV 2 mA 0 15 sec and for conventional angiography 65 kV 150 mA 0 07 sec The ordinary as well as the enlargement angiograms obtained in the arterial phase revealed a slight narrowing of the radial artery at the origin of the ramus palmaris superficialis but no abnormalities were evident in other parts of the vascular wall The radius of ramus palmaris superficialis was markedly bent, and numerous vessels arose from its terminal portion and branched off to surround the base of the tumour i e the tumour bed

The ordinary angiogram disclosed 0 1 mm blood vessels in the tumour bed but a homogeneous density was apparent in the interior of the tumour (Fig 3 inset)

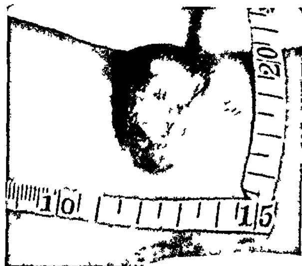


Fig 2 Skin cancer at the wrist joint

As the focal spot is extremely small, the tube current at a voltage of 125 kV is reduced to only 2 or 3 mA Roentgenography was therefore usually conducted at 100 cm FFD and 25 cm FOD Generally, in actual practice, an intensifying screen of medium speed, with film 'Kodak Royal Blue Brand', is used for thicker body parts The special heating filament of the tube can withstand more than 10 000 exposures

2 Conventional angiography and enlargement angiography of the same arterial phase In order to compare ordinary films with enlargement films, angiograms in the same arterial phase were obtained with both techniques The tube for producing the conventional angiogram was located 180 cm above the table, the central beam from the 2 mm focus being inclined 55° to the horizontal plane The distance between film and table was 10 cm To avoid overlapping from the enlargement tube, the film for obtaining the conventional angiogram was placed close to the beam, this film measured 12 × 16 cm and was placed at an angle of 35° to the horizontal plane

A supplementary table was attached to the main table, at an angle of 17 5° to the horizontal plane, the body part to be examined was positioned on this table By this arrangement, the central beams of both tubes subtend at an angle of 17 5° with the object to be examined, the exposures were made synchronously A test marker, consisting of four wires, 40 μ, 60 μ, 80 μ and 100 μ, respectively, in size, and arranged at intervals of 40 μ, 60 μ, 80 μ and 100 μ, was placed on the surface of the supplementary table in order to compare the sharpness of the image

Synchronous exposures of a skin cancer, located at the level of the base of



Fig 5 Skin cancer of the popliteal fossa of the right leg



Fig 6 Apparatus for serial angiography in fourfold enlargement A small focus tube is located below the radiographic table and a cassette changer above the patient

Clinical application of conventional and enlargement angiography

Serial angiography was performed in two stages and consisted of ordinary angiography followed by enlargement angiography

A 34 year old male had a 15 × 18 cm cicatrix extending downwards from the popliteal fossa resulting from a scald Two years previously a skin transplant had apparently been successful but about 2 months prior to his admission an erosion about 5 × 9 cm in size, had appeared at the site This became nodular and grew rapidly in size When examined, the tumour measured about 8 × 3 5 cm with the eroded wall raised 1 5 cm above the skin surface (Fig 5) Biopsy revealed formation of nests with irregular penetration



Fig 4 Angiogram obtained by the fourfold enlargement technique in the venous phase An increased number of vessels may be seen in the tumour bed and faintly outlined vessels are discernible in the tumour The conventional angiogram is shown as an inset (bottom left)

However, enlargement angiography of the tumour bed showed tortuous vessels, about 2 mm in diameter (Fig 3) The tips of these vessels were located at the hilum of the tumour, from which numerous 0 1 mm coiling vessels arose In addition, a great number of linear, faintly outlined vessels, about 0 1 to 0 2 mm in diameter, ran radially from three different parts of the tumour bed (cf description by e g LAGERGREN et coll 1960, 1961, LAGERGREN & LINDBOM 1962, MARGULIS et coll 1961, and MCALISTER & MARGULIS 1963) These two details were too fine to be discernible in the ordinary films The enlargement angiogram in the venous phase disclosed that the cutaneous veins were more extensively distributed than the arteries of the tumour bed and that they formed irregular networks (Fig 4)

It may therefore be stated that enlargement angiography revealed irregular proliferation of small vessels in the infiltrating part of the tumour as well as an increase in the number of fine vessels within the tumour, these details were not apparent in the ordinary angiograms The test marker in ordinary roentgenography could resolve 80 μ but not 60 μ, but up to 40 μ was resolved in enlargement roentgenography, in other words, more minute details were evident





F g 8 Indirect fou fold enlargem nt showing the formai on of the vessels in the tumour Conventional ang ogram shown as an inset (top r ght)



F g 9 Ang ogram n the venous pha e in fourfold magnification As compared w th the te al phase (fig 7) the cal bre of the tumour vein a e larger Conven t l ang gram as an iset



Fig 7 Angiogram in fourfold magnification in the arterial phase Tortuous vessels *of uneven contour in the tumour bed (white arrow) several branches radiate into* the lobulation

of epidermal cells into the dermis, epithelial pearls lay within the nests and numerous small parallel blood vessels ran through the connective tissue The tumour was diagnosed as a squamous cell carcinoma

A needle was introduced into the femoral artery and serial films of the right leg was obtained at 1 sec intervals (Fig 6) by the conventional angiographic method as well as by the direct fourfold magnification technique Three seconds after the injection of the contrast medium, proliferating blood vessels of 0 4 to 0 5 mm calibre were seen in the enlargement films (Fig 7) at the base of the tumour, forming the so called tumour bed Within this tumour bed, branches from the crural artery, separated by intervals of between 1 5 and 2 5 cm, supplied some of the larger nodules Numerous vessels, 0 2 to 1 0 mm in width and 3 to 15 mm in length, could be seen coursing from the hilum parallel to each other and perpendicular to the skin surface

The conventional serial films outlined the tumour bed, but neither the size nor the contours of the few individual blood vessels could be distinctly seen (Fig 8, top right) Difficulty also arose in determining the sites of the hila The blood vessels within the tumour were poorly defined in the ordinary roentgenograms A fourfold photographic magnification of these films was much

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less informative than the angiogram obtained with the fourfold enlargement technique (Fig 8, centre) The network of arterial branches was seen to be dense, and at this stage two or three veins became discernible under the skin As the examination proceeded, almost all the vessels became enlarged up to diameters of 0 6 to 0 8 mm

Dos Santos, in 1950, was first to publish the angiographic criteria of bone malignancy, and many authors, e g Abrams (1961), Begg (1955), Farinas (1937), Goree & Dukes (1963), and Lindgren (1945), have described peripheral tumour angiography Experimental microangiographic investigations were made by Lagergren et coll (1960, 1961), and by Lagergren & Lindbom (1962), who injected Micropaque into lower limbs that had been amputated for fibrosarcoma, osteogenic sarcoma and chondrosarcoma, for a study of the relationship between vascularity and degree of malignancy As characteristic findings these authors reported the observation of irregular reticular formations, brush like arrangements of fine vessels, or pathologic tumour vessels of irregular calibre

There are only a few reports on the appearances of vessels in dermal carcinoma Margulis et coll (1961) and McAlister & Margulis (1963) studied the post mortem vascular appearances of transplanted tumours of white rats by the indirect enlargement method and reported a characteristic vascular arrangement in some tumours, one of which was a brush like parallel arrangement

Direct enlargement angiography applied to the living subject thus permits examination of extremely small vessels, and it would appear to be a method that will help widen the domaine of applicability in roentgen diagnosis

SUMMARY

A roentgen tube with a very small focal spot was employed in angiography in two cases of dermal carcinoma to obtain fourfold magnification The enlargement angiograms revealed the vessels in much finer detail than the conventional angiogram

ZUSAMMENFASSUNG

Um eine vierfache Vergrösserung zu erhalten wurde bei Angiographie in zwei Fällen von Hautkarzinomen eine Röntgenröhre mit sehr kleinem Brennfleck verwendet Das Vergrösserungsangiogramm war viel mehr detailliert als das konventionelle Angiogramm

RÉSUMÉ

Les auteurs ont utilisé un tube de radiodiagnostic à foyer très fin pour obtenir un agrandissement de quatre fois en angiographie dans deux cas de cancer de la peau Les angiographies agrandies ont révélé des détails beaucoup plus fins sur les vaisseaux que l angiographie ordinaire

FROM THE ROENTGENDIAGNOSTIC DEPARTMENT, UNIVERSITY HOSPITAL, LUND, SWEDEN, AND THE DEPARTMENT OF RADIOLOGY STANFORD UNIVERSITY SCHOOL OF MEDICINE, PALO ALTO CALIFORNIA U S A

SPILLOVER FLOWMETER

A preliminary report

by

TORD OLIN and HELEN REDMAN

Selective catheterization of branches of the aorta has been widely used in the last few years During injection of contrast medium through the catheter reflux into the aorta occurs if the injection speed is high enough This finding suggested the possibility of determining the blood flow by cineradiography

Principle A catheter is introduced into the aorta with the tip in the branch where flow is to be measured Contrast medium is injected through the catheter and the flow is followed fluoroscopically and with cineradiography At sufficient injection rate the medium starts leaking back into the aorta during diastole Further increase in injection rate causes back leak during systole The injection rate is registered and therefore the systolic and diastolic blood flow can be calculated The blood pressure is also recorded so that the duration of the systolic and diastolic flow can be determined and the mean flow calculated

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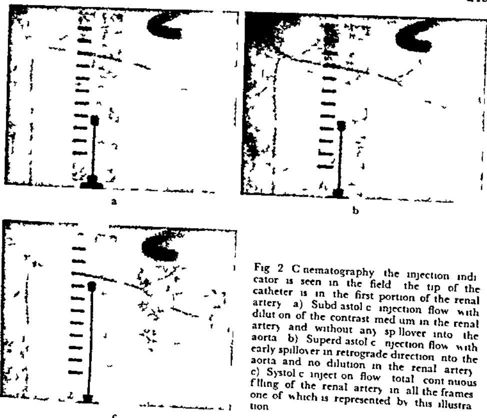


Fig. 2. Cinematography: the injection indicator is seen in the field; the tip of the catheter is in the first portion of the renal artery. a) Subdiastolic injection flow with dilution of the contrast medium in the renal artery and without any spillover into the aorta. b) Superdiastolic injection flow with early spillover in retrograde direction into the aorta and no dilution in the renal artery. c) Systolic injection flow: total continuous filling of the renal artery in all the frames, one of which is represented by this illustration.

diastole the highest number of frames per 0.1 ml with minimal backflow, the highest number of frames per 0.1 ml with continuous renal artery filling (Fig. 2). The diastolic flow is calculated by taking the arithmetic mean of the counts without backflow and with minimal backflow. The systolic flow is calculated from the continuous filling figure. The mean flow is calculated by weighting the diastolic and systolic figures in accordance with the period for arterial systole and diastole judged by the blood pressure curve. In rabbits the systolic period is about one third of the total cycle.

The general blood pressure shows almost no change during these injections and there is little change in renal blood flow during or following injection of Renografin 60 %, as shown by simultaneous direct blood flow recordings.

The results from two rabbits are given in a Table. Rabbit No 3 was studied without magnification and rabbit No 2 represents an example of the use of magnification technique.



Fig. 1. Anatomy: the tip of the catheter is in the first portion of the left renal artery which is seen to run transversely and give off the suprarenal lumbar artery as its first branch. It divides into dorsal and ventral branches at the hilus of the kidney.

Experiments. The renal blood flow was studied by this method because it can be easily compared with flow data obtained by means of many other techniques, including clearance studies, dye dilution techniques, and venous return flowmeters. *Eight big rabbits were used for the preliminary evaluation.*

Following general anesthesia, the left renal artery is catheterized from the right femoral artery (Fig. 1) (ADAMS, OLIN & REDMAN 1965). Blood flow is measured by a photoelectric drop flowmeter connected between the left renal vein and the left superficial jugular vein. The blood flow, as well as EKG, blood pressure, respiration, and injection are recorded on a multichannel oscillograph. *Injections of approximately 1 ml Renografin 60 %* are *made* into the renal artery. The injection rate is recorded by an indicator placed in the field. Cineradiography is performed using an image intensifier, a small focal spot, a speed of 48 frames/sec, and no grid. A magnification technique has sometimes been used. Studies of blood flow have also been made following alteration of the blood flow by selective renal artery injection of drugs, such as adrenalin and papaverine.

Results

The cine strip is evaluated and the following counts are made: the lowest number of frames per 0.1 ml contrast medium injected without backflow in

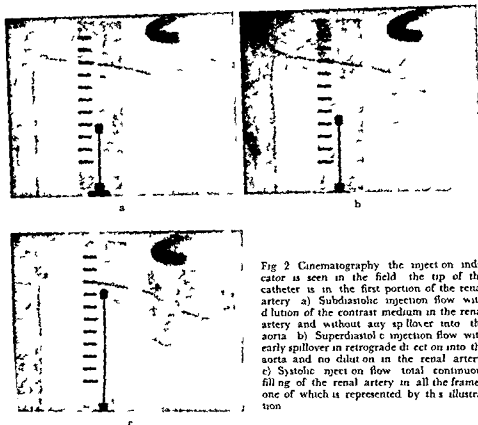


Fig 2 Cinematography the inject on indicator is seen in the field the tip of the catheter is in the first portion of the renal artery a) Subdiastolic injection flow with d lution of the contrast medium in the renal artery and without any sp llover into the aorta b) Superdiastol c injection flow with early spillover in retrograde di ect on into the aorta and no dilut on in the renal artery c) Systolic nject on flow total continuous fill ng of the renal artery in all the frames one of which is represented by th s illustration

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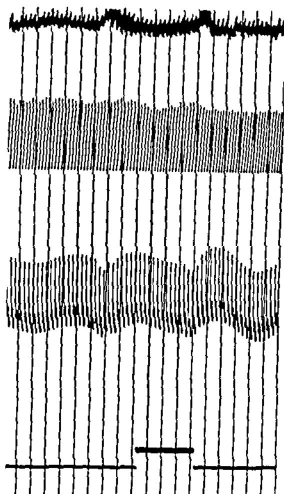


Fig. 3. Recording (from below) of injection, blood pressure, left renal blood flow and EKG following injection of 1.0 ml Renografin 60. — no change is noted.

Discussion

In the past, different radiographic methods have been used in flow studies. The linear velocity of flow has been studied, especially in the aorta and femoral arteries (GIDLUND 1956, GUNTERT & ZIMMER 1957, BUCHNER 1962). The circulation time has been studied angiographically and with isotopes (GREITZ 1956). These methods, however, do not give any real information about the volumetric blood flow.

The rate of washout of contrast material injected into the renal vein is clearly related to the renal blood flow (ABRAMS et coll. 1963). The method is based on the fact that the renal vein will usually not appreciably diminish in size in renal artery stenosis.

Table

Rabbit	Cine flow ml/sec			Drop flow ml/sec
	Diastolic	Systolic	Mean	
3	0.19	0.57	0.30	0.43
3	0.18	0.52	0.29	0.27
3	0.22	0.52	0.3[illegible]	0.26
2	0.35	0.54	0.41	0.43
2	0.33	0.4[illegible]	0.37	0.35

JEPPSSON & OLIN (1960) injected contrast medium in the rabbit into one of the internal carotid arteries which was ligated proximally. At a sufficient injection rate complete filling of the circle of Willis as well as the basilar artery and the opposite carotid siphon was obtained. This rate was in good agreement with other determinations of the cerebral blood flow (LEVEVE 1957). The volumetric determinations of cerebral blood flow by JEPPSSON & OLIN formed the basis for the current more general blood flow determinations.

The volumetric blood flow is a function of three factors: blood pressure, viscosity and flow resistance of the peripheral vascular bed. Local blood pressure is not affected by the injection since the catheter is small compared to the renal artery, it is only introduced a short distance and there is a wide communication with the aorta. No change in systemic blood pressure has been demonstrated by our curves (Fig. 3). The apparent viscosity of the mixture perfusing the kidney is dependent upon the viscosity of the contrast agent and the degree of sludging of the erythrocytes. The combined effect of these factors on renal blood flow is minimal with Renografin 60 %, as shown by our continuous recordings during and following injection and those presented by LINDGREN (1961).

In order to ensure accurate flow determinations the cinematographic recording technique must be optimal. The recording speed must be reliable and as high as possible in order to detect the earliest backflow. A small focal spot and the magnification technique are employed to obtain the highest resolution. Using good techniques, our flow determination shows a variation of 5 per cent from the actual count. Without the optimal cinematographic technique the determinations showed greater variations. The flows determined by the spillover technique are usually a little too high because of the problem of determining early backflow.

The spillover flowmeter can be generally used where a small branch vessel originates from a larger vessel. Diastolic backflow must not normally be present

The celiac axis, superior mesenteric, renal and vertebral arteries are suitable for this procedure

Studies in dogs and human subjects are currently being made, and the results will be analyzed in a later report Modifications of the spillover technique are also being evaluated, including the use of a solution of saline with measurement of the electric resistance in the blood stream at the vessel orifice Heated, or cooled, solutions using thermistors or thermocouples, as well as radioactive isotopes with scintillation detectors may also be used

SUMMARY

A cineradiographic flowmeter constructed on the basis of the spillover technique is described

ZUSAMMENFASSUNG

Ein cineradiographischer Blutstrommesser konstruiert auf der Basis der Spillover Technik, wird beschrieben

RÉSUMÉ

Description d un débitmètre cinéradiographique basé sur la technique du regorgement

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Book Reviews

L'ANGIOGRAPHIE de l'artere carotide interne chez le sujet normal Par D Dilenge 230 pages et 156 figures Masson et Cie Paris 1962 Prix 95 NF

This book describes in detail the normal angiographic anatomy of the internal carotid artery The presentation is based on a normal material comprising 100 internal carotid angiographies scrupulously selected and on an exhaustive study of the actual literature After an introduction dealing with different contrast media methods of punction and injection projections and exposure technique the main vessels in the actual vascular area are discussed The conventional roentgenographic anatomy is compared with angiographic findings and the normal variations are often analysed in the light of statistical figures

Numerous reproductions of high quality supplemented with instructive drawings, facilitate the reading The legends are expressive and facilitates an isolated study of the illustrations

As the monograph gives actual information about the technique of carotid angiography as well as about normal anatomical variations it will first of all be recommended to those starting their neuroradiologic training However even for the radiologist experienced in the neuroradiological field the book should be useful as a textbook

Herman Lodin

LA DUODENOGRAPHIE HYPOTONIQUE Exploration élective de l ampoule de Vater et de la tête du pancréas Par P Jacquemet et D Liotta 181 pages 93 figures et bibliographie Masson et Cie Paris 1963 Prix 60 F

La duodénographie hypotonique créee par Liotta associe l hypotonie duodénale obtenue par des agents pharmacodynamiques et l injection de bouillie barytee sous pression par une sonde directement dans le duodénum

Les auteurs insistent sur l existence de sphincters fonctionnels limitant a ses deux extrémités la deuxième portion du duodénum qui permettent de la distendre par le moyen de contraste Pour le reviewer cette distension est la grande supériorité de cette méthode sur les autres techniques de duodénographie hypotonique elle moule étroitement la paroi duodénale sur les organes voisins essentiellement la tête du pancréas et l ampoule de Vater dont les déformations peuvent être décelées précocement

La description des images anormales est basée sur 150 cas tous vérifiés par opération et la plupart aussi par biopsie la matériel comprend 80 pancréatites chroniques 15 cancers du pancréas 12 cancers de l ampoule de Vater et 25 calculs de la partie inférieure du cholédoque

Les auteurs analysent les résultats de façon très détaillée et honnête la duodénographie hypotonique conduit assez souvent au d agnostic de nature des lésions dans un grand nombre de cas elle permet au moins un d agnostic de siège exact et précoce qui contribue à faire poser l indication d un traitement chirurgical en temps utile

Ce travail est illustré de 93 figures de bonne qualité comprenant pour la plupart plusieurs illustrations et un schéma

J Roulleau

RADIOGRAPHY OF INFANTS AND CHILDREN By Donald B Darling 193 pages, 229 illustrations and 79 tables Charles C Thomas Springfield, Illinois 1963 Price 16 50 dollars

Publications on the roentgen examination technique in children are few This book gives a clear and concise yet in many respects comprehensive account of the technical aids and roentgenographic procedures in paediatric diagnosis It is obviously based on wide personal experiences and will undoubtedly fill a gap The presentation is logical and generously illustrated and a justifiably large section is devoted to the technique suitable in infants It is probably unavoidable in a work of this nature that the recommendations must be highly standardized and that no space can be reserved for special projections of value in diagnosis The investigatory nature of the procedures would propably have been more clearly stressed and the impression of mere photography reduced if the choice of projections had been discussed in more detail It cannot be said that the exposure technique is up to-date but this is probably due to local conditions Short exposure times and correspondingly higher kilovoltages are for instance, recommended in the introduction but this has not been applied in the technique for the examination of the heart and lungs Another feature that may be mentioned is the almost consistent use of unnecessarily large diaphragm openings with resultant radiation hazards to the patient The author s extensive use of names for standard projections has an irritating effect on a reader accustomed to international terminology The absence of concrete viewpoints on the special techniques necessary with automatic exposure time selectors and on the utilization of the intensifying screen and television technique in paediatric diagnostic radiology is serious in a modern work A comprehensive tabular survey of the exposure data in all the ordinary radiographic procedures and in a few of the more uncommon forms used in infants and children appear at the end of the book This would have been of value if essential information concerning the characteristics and outputs of the roentgen apparatus and tubes had been included

Ulf Rudhe

ERWEITERUNGEN DES SPINALRAUMES RADIOLOGISCHE BEURTEILUNG UNTER BESONDERER BERÜCKSICHTIGUNG DER SYRINGOMYELIE By Peter Hagermann 99 Seiten 35 Abbildungen und 12 Tafeln Gustav Fischer Verlag Jena 1963 Preis 16 90 DM

Any work dealing with roentgenologic investigations of the spinal canal and its contents will always attract attention Although the present book may not contain anything new for those familiar with the field it should be of some value to readers who are interested in neuroradiologic procedures The current concern of the author is directed on measurements of the spinal canal in syringomyelia which present aspects not previously considered A statistical investigation of the sagittal and frontal widths of the spinal canal in normal subjects as well as the cross sectional area of the spinal canal at all levels are included A kind of surface index correlates to some degree this area with the size of the corresponding vertebral body The results of the investigation of the normal material is applied to 100 cases of syringomyelia The author establishes no statistically significant differences in the values of the different parameters between normal subjects and those with syringomyelia The variations in the width of the spinal canal were however appreciably greater in the latter and above normal values were found in between 15 and 20 % of them The author therefore concludes that measurements of the spinal canal are often of help in distinguishing changes due to the disease

Bengt Liliequist

ACTA RADIOLOGICA

OFFICIAL ORGAN OF THE RADIOLOGICAL SOCIETIES OF
DENMARK FINLAND NORWAY AND SWEDEN

Vol 4 DIAGNOSIS 1966
Fasc 3 May

ROENTGEN DIAGNOSIS OF RUPTURE OF ANTERIOR CRUCIATE LIGAMENT

by

S O LILJEDAHL N LINDVALL and J WETTERFORS

Injuries of the cruciate ligaments are the most serious of the internal derangements of the knee joint Unless adequately treated a cruciate ligament injury will generally lead to permanent instability of the joint with accompanying rapid wasting of the joint cartilages Degeneration and rupture of the menisci usually follow Rupture of the posterior cruciate ligament is relatively rare, whereas complete or partial rupture of the anterior cruciate ligament is fairly common It is certainly more common than is evident from, for instance the annual reports from various Swedish hospitals many of the acute ruptures are overlooked because of the difficulty of diagnosing these injuries clinically or by arthrography The injury is sometimes overlooked even at an arthrotomy for an associated meniscus rupture if the cruciate ligaments are not inspected or subjected to a *sufficiently careful* palpation Rupture of the cruciate ligaments should be treated operatively with suture of the ligaments immediately after the accident, in order to achieve complete anatomical and

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functional restitution (Palmer 1938, Liljedahl, Lindvall & Wetterfors 1961, 1963).

A great number of patients with chronic cruciate ligament injuries have been treated at this hospital (during the last 4 years). Most of them had been examined in connection with the accident, and arthrography had sometimes been performed but failed to yield the diagnosis. The purpose of this study has been to try to establish the value of arthrography as an aid in the diagnosis of injuries of the anterior cruciate ligament.

Earlier arthrographic studies. Rupture of the anterior cruciate ligament generally occurs in its substance, avulsion of bone fragments from the attachments occurred in about 40 % of the cases of the present series (Liljedahl, Lindvall & Wetterfors 1965). A fracture at the attachment of the ligament can be diagnosed in ordinary films, but arthrography is necessary for the demonstration of a rupture in the ligamental substance. Several works dealing with the use of arthrography in diagnosing knee joint injuries have been published but only a few authors have discussed the possibility of demonstrating a cruciate ligament injury. Lindblom (1938) described the arthrographic appearances of the normal and the ruptured cruciate ligament; he used a positive contrast medium (Perabrodil 35 %). A large and irregular contrast defect was often present at the site of the ligament, explained by the blood in the rupture region in fresh ruptures of the anterior cruciate ligament. An exact diagnosis could not be made but roentgenographic demonstration of excessive forward mobility supported the diagnosis. The same held true when the anterior cruciate ligament remained in its normal position after the rupture. In old chronic injuries, considerable pooling of contrast medium occurred at the site of the anterior cruciate ligament. This ligament atrophies relatively rapidly because its vascular supply is impaired as a result of the injury. The intact posterior cruciate ligament is then more clearly defined; similar appearances were seen in acute injuries.

Some authors deny the possibility of diagnosing a cruciate ligament rupture by arthrography alone. Palmer (1938) stated that 'in order to be certain, the roentgen diagnosis of a cruciate band injury should always be supported by clinical findings', and Fischer (1952) expressed the same view. Fagerberg (1956) and Philippon (1957), on the other hand, considered that ligament ruptures can be diagnosed roentgenologically. Philippon used air and examined the cruciate ligaments in anteroposterior films; complete ruptures could be demonstrated. Fagerberg used a positive contrast medium and tomography, which he considered most satisfactory for investigating the cruciate ligaments as well as their ruptures. Many authors have in recent

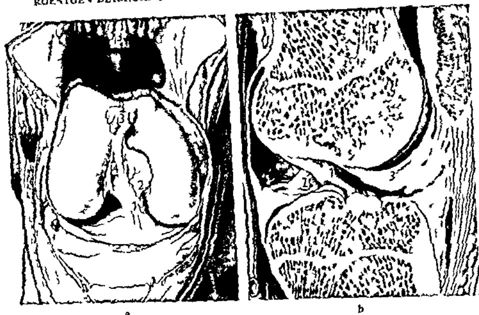


Fig 1 Normal anatomy a) Anterior part of knee joint b) Anterior ligament from the medial aspect 1 — anterior cruciate ligament 2 — posterior cruciate ligament 3 — patellar synovial fold 4 — fat lobule at femoral attachment of anterior cruciate ligament (From VON LANZ WACHSMUTH)

years discussed the advantages of double contrast arthrography (VAN DE BERG & CREVECOEUR 1953 RUTTIMAN 1957 DJIAN CALOP & PUCHOT 1959 ANDREN & WEHLIN 1960 ZAKRISSON 1960 and others) but none of them has discussed the *possibility* of demonstrating cruciate ligament ruptures by this method

Anatomy and function of anterior cruciate ligament (Fig 1) The anterior cruciate ligament arises from the medial aspect of the posterior part of the lateral femoral condyle near the intercondylar fossa and varies slightly in extension It passes obliquely forwards downwards and medially it is attached in front of and close to the intercondyloid eminence and directed towards the anterior part of the internal semilunar cartilage Since its base extends over a greater area than its attachment the ligament spreads fanwise and is therefore attached in front of the axis of rotatory movement of the lower leg The ligament on its anterior and lateral aspects is clothed with synovial membrane almost over its entire length No synovial covering is generally present medially at the level where it is transversed by the posterior cruciate ligament The two liga

ments may have a common synovial covering in this region although a joint recess may occasionally be interposed between them Synovial membrane clothes only a small area of the posterior aspect of the ligament at the level of the lateral intercondylar eminence The recess, which passes behind the ligament, is sometimes wider than normal and a larger part of the posterior surface is then covered with synovial membrane The cruciate ligament usually has a rounded anterior surface when cut transversely but occasionally the surface may be wedge shaped, with the apex directed anteriorly, particularly in its middle part Only those parts of the cruciate ligament that are covered with synovial membrane will be seen at arthrography The upper part of the anterior surface may sometimes be concealed by a small fat lobule

The different parts of the anterior cruciate ligament are alternatively taut and relaxed in different positions of flexion of the joint The anterior portion, being the major part of the ligament, tightens on extension With about 20° flexion the whole ligament is maximally relaxed but with further flexion it tightens again The ligament relaxes on outward rotation of the lower leg and tightens on inward rotation The whole ligament is taut on hyperextension, and will thus prevent abduction mobility even with complete insufficiency of the medial collateral ligament

A forward mobility of about 0 5 cm is normally present when the knee joint is flexed There is no fixed limit for the range of the physiologic forward mobility but it should not exceed 1 cm Comparison should always be made with the normal knee joint (PALMER 1938)

Clinical signs The anterior cruciate ligament may be ruptured by hyperextension or by abduction or adduction strains of the knee joint A hyperextension strain may produce an isolated cruciate ligament injury If the injury arises from abduction or adduction strain, the medial or lateral collateral ligament of the knee may also be torn, sometimes associated with an injury of the lateral or medial semilunar cartilage, with or without fracture of the lateral or medial tibial condyle

The characteristic clinical sign of an anterior cruciate ligament rupture is excessive forward mobility of the tibia on the femur This may often be demonstrated if the examination is carried out immediately after the accident, within a few hours the examination is made difficult by painful fixation of the joint Excessive forward mobility is also difficult to demonstrate when the injury to the cruciate ligament is isolated Excessive abduction mobility on hyperextension of the joint is a sign of complete rupture of the cruciate ligament although this may be difficult to demonstrate with a slight extension defect These signs are often absent in partial ruptures It may be difficult

Table 1

Cases (51) with operatively verified anterior cruciate ligament injuries in series I A

Arthrographic evaluation	Primary diagnosis	Findings at re-examination
Established injury	25	17
Probable injury	10	22
Normal ligament	10	0
Non assessable ligament	6	12

clinically to demonstrate a recent anterior cruciate ligament injury unless the examination is made under anaesthesia that produces complete muscle relaxation

Present material

Technique Arthrography was performed by the technique described by LINDBLOM (1938, 1948) Perabrodil was the contrast medium used up to about 1956 it was then replaced by Urografin 30 % Since the middle of 1959 the procedure has been modified as follows The compression over the supra-patellar recess having been removed films are obtained in the lateral projection with the joint flexed to between 60 and 90 and with and without the head of the tibia pushed maximally forwards

Material Series I comprises all the 91 patients treated at the hospital during the period 1940—1962 in whom complete or partial rupture of the substance of the anterior cruciate ligament was evident at operation and in whom arthrography was performed preoperatively

Table 2

Operatively verified complete or partial ruptures of the anterior cruciate ligament in series I B (40 cases)

Findings at operation	Arthrographic findings		
	Complete rupture	Partial rupture	Normal ligament
Complete rupture	20	1	
Partial rupture	3	13	3

Table 3

Comparison between operation and arthrographic findings in series II (36 cases)

Findings at operation	Arthrographic findings		
	Rupture of anterior cruciate ligament	Normal cruciate ligament	Non-assessable ligament
Rupture	12	1	1
Normal	4	18	

Series I is divided into two groups, each examined by a different technique. Group A consists of 51 patients who were examined between 1940 and the middle of 1959, and group B is made up of 40 patients examined from the middle of 1959 up to December 1962.

Series II comprises 36 patients in whom the cruciate ligaments were inspected at operation immediately after arthrography. Twenty-two patients had normal cruciate ligaments and 14 had torn anterior cruciate ligaments. The patients were selected by the surgeons, and the films were examined by the radiologist who knew nothing about the clinical data or the operative findings. The results of the interpretation were compared with the findings at operation. Series II was selected for the purpose of finding out the cause of discrepancy between the arthrographic and the operative findings in series I A.

Results and Discussion

The radiographic findings in series I A were divided into 'cruciate ligament injury', 'probable cruciate ligament injury', 'normal cruciate ligament', and 'non-assessable cruciate ligament'. The films were re-examined and the primary radiographic diagnosis was compared with the results of the re-examination. *The results are given in Table 1.*

The roentgenographic findings in series I B were divided into 'complete rupture' (complete or almost complete rupture involving three quarters of the thickness of the ligament), 'partial rupture' (overstretched cruciate ligament) and normal ligament. It will be seen from Table 2 that there was complete agreement between the radiographic and the operation findings in 33 out of 40 cases. Neither excessive forward mobility nor abduction instability could be demonstrated with certainty, not even under anaesthesia in two cases, yet arthrography and subsequent arthrotomy revealed complete or almost complete cruciate ligament rupture.



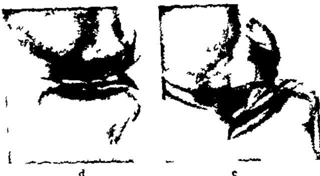


Fig 2 Normal anterior cruciate ligaments a) Knee extended Cruciate ligament not seen recesses compressed b) Knee flexed to 30 Upper anterior outlines of ligament visible recesses widened c) Knee flexed to 60 The whole of the anterior outlines of the ligament visible d) Knee extended Part of anterior outlines visible recesses compressed e) Knee flexed to 60 The whole of the anterior outlines evident

The radiographic findings in series II were divided into normal cruciate ligament, cruciate ligament injury, and non assessable ligament It will be seen from Table 3 that a comparison between the radiographic and the operation findings revealed that four intact cruciate ligaments were assessed as ruptured and one ruptured ligament was considered normal The ligament was not assessable in one case in which it was ruptured

The number of patients admitted to the hospital in the later part of the 1950s with chronic cruciate ligament injuries increased This prompted interest concerning the early diagnosis and prompt active treatment of such injuries The incidence of acute anterior cruciate ligament injuries has consequently increased Experience over several years showed that there was some discrepancy between the clinical arthrographic and operation findings The arthrographies had been carried out according to the technique described by LINDBLOM (1938 1948) Films of the knee joint in the lateral position, with the head of the tibia pushed forwards were generally obtained only when a cruciate ligament rupture was probable clinically An operatively verified material (series II) comprising both intact and injured cruciate ligaments was first examined in order to determine the cause of the discrepancy between the



Fig 3 Normal anterior cruciate ligaments a) Distinct anterior outlines b) Lateral films obtained without (upper) and with (lower view) the head of the tibia pushed forwards In the former the middle part of the ligament is indistinct and in the latter the anterior outlines are clearly seen

arthrographic and operation findings Among the ligaments assessed as ruptured four were normal, and among those assessed as normal one was completely ruptured A further scrutiny of the five arthrograms revealed that the lateral view had been obtained with the knee only slightly flexed and that no films had been obtained with the head of the tibia pushed forwards The lateral views in some of the others were equally unsatisfactory, and in several they were underexposed although the 'probable' diagnosis was correct

All the arthrograms of the operatively verified anterior cruciate ligament ruptures from the years between 1940—1959 were re examined with the object in view to find out how often an error in interpretation of the films of the cruciate ligament was due to arthrography having been inaccurately

performed It was found that even when the presence of a cruciate ligament injury was known both the primary roentgen diagnosis and the findings on re-scrutiny of films were often incorrect, the cruciate ligaments could sometimes not be assessed

The study of these two series thus showed that in virtually all the cases in which the arthrographic and operation findings did not agree, the discrepancy was due to unsatisfactorily performed arthrographies and not to inherent failures in the method itself in the radiographic demonstration of a cruciate ligament injury The ruptures had not been detected when the lateral films had been obtained with the knee joint only slightly flexed and without the head of the tibia being pushed forwards Moreover, the contrast medium was sometimes too diluted to enable an interpretation of the films or the lateral films had been underexposed

The anterior cruciate ligament is as mentioned earlier, fully relaxed when the joint is flexed to about 20 the larger anterior part of the ligament is at maximum tension on hyperextension It might therefore be reasonably concluded that when the anterior cruciate ligament is to be studied the joint should be examined on extension However the recesses that cover the cruciate ligament are maximally compressed on extension of the knee joint and generally almost completely devoid of contrast medium in this position therefore the cruciate ligament will not be rendered visible The recesses are widened (LINDBLOM 1938) and filled with contrast medium when the knee is flexed so that the cruciate ligament can be seen The cruciate ligament is tighter on flexion to between 60 and 90 than on flexion to about 20 the lateral film should therefore be obtained with the knee joint flexed to between 60 and 90 (Fig 2) The extent to which the anterior and posterior outlines are visible depends upon the size of the recesses and on the presence or absence of a fat lobule at the upper attachment (Fig 3a) *Because the* anterior part of the ligament is not fully stretched in this position the anterior contour within the middle part may be indistinct even when the ligament is intact, and this may give the impression that it is defective When the head of the tibia is pushed forwards the anterior part tightens and the anterior contour of the ligament is clearly seen (Figs 3b and 4)

The authors since the middle of 1959 have consistently followed the principle that the lateral films must be obtained while the knee joint is flexed to between 60 and 90 and that *irrespective of the* clinical findings films should also be obtained with the head of the tibia pushed forwards and the films should be adequately exposed. The result of this modification of the arthrographic technique is seen from Table 2 which indicates a very good agreement between the arthrographic and operation findings In three patients in whom







Fig 4 Fig 5 Fig 6

Fig 4 Normal cruciate ligaments Lateral films obtained without (upper) and with head of tibia pushed forwards (lower view) In the former the anterior outlines of the anterior cruciate ligament are indistinct while in the latter they are clearly visible The greater parts of the posterior outlines of the anterior cruciate ligament as well as of the anterior outlines of the posterior ligament are clearly seen in the lower view

Fig 5 Acute complete rupture of anterior cruciate ligament Blood conceals the greater part of the ligament in the upper view but in the lower (after suture) the ligament is distinctly outlined

Fig 6 Complete rupture of anterior cruciate ligament at tibial attachment Lateral films obtained without (upper) and with (lower view) head of tibia pushed forwards The anterior cruciate ligament is hanging lax in the lower view the posterior cruciate ligament is fully relaxed

the findings at arthrography suggested almost complete or complete rupture, operation revealed partial rupture, the cruciate ligament was much narrower and more lax than normal, and had small tears in its substance In three patients, in whom the arthrograms were interpreted as normal, operation revealed partial ruptures of the posterior quarter of the anterior cruciate ligament, in two close to the intercondylar eminence and in one patient at the upper attachment, of such an order that suture was not indicated The anterior cruciate ligament in the former two patients was distinctly outlined anteriorly but the posterior contour could not be seen, nor could the anterior outlines of the posterior cruciate ligament be seen in one of them which ought to have led to a partial rupture of the anterior cruciate ligament being suspected The film of the

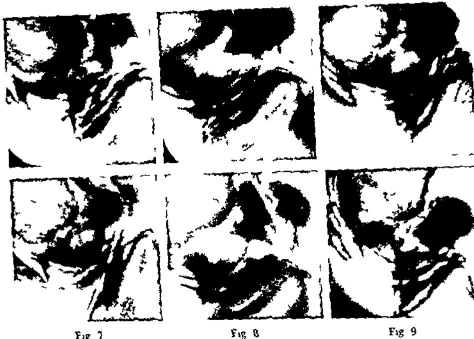


Fig 7 Acute rupture of anterior cruciate ligament *Upper view* Lateral Probable cruciate ligament rupture *Lower view* Lateral with head of tibia pushed forwards Anterior cruciate ligament not seen the posterior cruciate ligament is relaxed

Fig 8 Chronic complete rupture of anterior cruciate ligament Anterior cruciate ligament not evident in the lateral films either in film without (upper) or with head of tibia pushed forwards (lower view) Large contrast pool at the site of the ligament

Fig 9 Acute complete rupture of anterior cruciate ligament Before operation (upper view) the anterior cruciate ligament is not seen and there is a large contrast pool at the site of the ligament After operation (lower view) the ligament is visible

anterior cruciate ligament in the third patient was difficult to interpret because a wide duplication of the synovial membrane from a Hoffa s fat pad was attached to the whole front part of the ligament The film was primarily interpreted as showing no evidence of rupture but at the same time it was suggested that the cruciate ligament should be checked at the subsequent arthrotomy for a meniscus rupture The completely torn cruciate ligament which had been assessed as partially ruptured and overstretched, was clearly outlined anteriorly in the arthrogram The ligament was hanging lax and did not tighten even when the head of the tibia was pushed forwards and the posterior cruciate ligament relaxed At operation the anterior cruciate ligament at first sight appeared quite normal but when the upper attachment

was palpated with a hook the ligament was found to be completely torn, only a few fibres at the back and the synovia were intact

In the material now discussed ruptures in the ligamental substance were localized at the upper and the lower attachments as well as in the middle of *the ligament, and tears in the substance* were more common than avulsion of bone fragments from the attachments (LILJEDAHL, LINDVALL & WETTERFORS 1965) Large contrast filling defects, concealing the greater part of the anterior cruciate ligament, were present in only two patients, although arthrography was carried out within 24 hours in seven patients (Fig 5) In one of these two patients there was distinct excessive forward mobility, although the anterior part of the cruciate ligament was not outlined within the part adjacent to the tibia not concealed by the filling defects Arthrography repeated 6 days later in the other patient established the diagnosis, as no filling defects were then present It could be directly demonstrated in the other patients that the anterior cruciate ligaments were completely or partially torn The tibial end of the ligament was seen lying against the tibia in some instances of fresh rupture with the rupture situated in the middle of the ligament or higher up The ligament seemed normal in arthrograms obtained without the head of the tibia being pushed forwards if the rupture had occurred in the lower or the upper attachment It was evident in films obtained with the head of the tibia pushed forwards that the cruciate ligament was not taut but still fully relaxed, or that the outlines of the ligament had disappeared, indicating that the ligament was torn (Figs 6 and 7) The cruciate ligament was not seen but there was a contrast pool at the site of the ligament in most instances of fresh ruptures, and particularly in chronic cases (Figs 8 and 9) Partial ruptures and overstretched cruciate ligaments could also be demonstrated with the method described by taking films with the head of the tibia pushed forwards The cruciate ligament as depicted in the lateral view was then more relaxed than normally, with ill defined or irregular anterior outlines When the head of the tibia was pushed forwards, the anterior cruciate ligament tightened while the posterior relaxed (Figs 10 and 11) The tibia can never be pushed so far forward that the posterior cruciate ligament will relax visibly, if the *anterior cruciate ligament is intact, although marked excessive forward* mobility may be present in the absence of cruciate ligament injury (PALMER 1938) It was not always possible arthrographically to distinguish with certainty a complete from a partial rupture The cruciate ligament was identified in wholly intrasynovial complete ruptures and the appearances resembled those of partial rupture in films obtained with the head of the tibia pushed forwards

Experiences over these last three and a half years indicate that it should







Fig. 10. Overstretched anterior cruciate ligament. Ligament hanging lax in the upper view. In the lower view film obtained with head of tibia pushed forwards, excessive forward mobility with anterior cruciate ligament tightened and posterior cruciate ligament relaxed.

Fig. 11. Almost complete rupture of anterior cruciate ligament. Upper part of ligament hanging lax in upper view. In the lower view with *the head of tibia* pushed forwards a few thin fibres remain intact.

be possible to demonstrate a normal anterior cruciate ligament by arthrography if the examination is made with a positive contrast medium. There are, however, extremely rare instances in which the ligament may be so markedly wedge shaped that its anterior contour is not sharply defined against the surrounding contrast medium (LINDBLOM). The patellar synovial fold may be hypertrophic and conceal part of the anterior contour of the ligament; two such cases have been observed. A film obtained with the head of the tibia pushed forwards in one of these disclosed, however, that the lower part of the cruciate ligament tightened normally and that the continuity of the ligament was evidently intact. The observations in the other case have already been mentioned. A hypertrophic *Hoffa's fat* pad may be superimposed on the cruciate ligament and conceal it. This has been observed in only one instance

however On the other hand, the cruciate ligament sometimes appeared quite *normal at rest but when the head of the tibia was pushed forwards* it moved up against an enlarged Hoffa's fat pad, so that the anterior outlines of the ligament disappeared, the lower part of the cruciate ligament tightened normally, however

The investigation also revealed that the posterior outlines of the anterior cruciate ligament and the anterior outlines of the posterior cruciate ligament may occasionally be seen in almost their whole extent, this sometimes occurred with both ligaments in the same joint, or with only one of them, without the other one being ruptured (Fig 4) The anterior contour of the recess that surrounds the lateral femoral condyle may easily be mistaken for the posterior contour of the anterior cruciate ligament The anterior contour of this recess is curved, with the convexity forwards (FAGERBERG 1956), and lies in front of the posterior contour of the ligament If the said mistake is made, the films *may be erroneously interpreted as showing partial rupture of the ligament* since the latter looks narrower than normal

Conclusions

Arthrography of the knee joint should always be performed in such a way that the semilunar cartilages as well as the cruciate ligaments can be studied It is extremely important to demonstrate the cruciate ligaments in acute injuries produced by typical trauma and in injuries with *haemarthrosis* without fracture This conclusion is based on the clinical fact that the successful treatment of total cruciate ligament rupture requires surgical intervention as *soon as possible after the accident* (LILJEDAHL, LINDVALL & WETTERFORS 1965) With a very few exceptions, normal cruciate ligaments can always be demonstrated by arthrography with a positive contrast medium, and with adequately exposed lateral films and the joint flexed to between 60° and 90°, as well as with films with the head of the tibia pushed forwards Tomography is unnecessary In the absence of normal anterior contours of the cruciate ligaments, and neither excessive forward mobility nor abduction instability on hyper-extension is evident clinically, the joint should always be examined for excessive forward mobility and abduction instability with the patient in complete muscular relaxation under anaesthesia Arthrographic evidence of acute cruciate ligament rupture is an indication for arthrotomy

SUMMARY

An account is given of a series of 91 patients with operatively verified anterior cruciate ligament injuries in which arthrography had been performed The possibility and the value of the arthrographic demonstration of injuries to the anterior cruciate ligament are discussed

ZUSAMMENFASSUNG

Beschreibung einer Serie von 91 Patienten die Verletzungen des vorderen Kreuzbandes hatten die operativ bestätigt und vorher arthrographisch untersucht worden waren Die Möglichkeiten und der Nutzen der Arthrographie für vordere Kreuzbandrisse wird erörtert

RÉSUMÉ

Les auteurs présentent une série de 91 malades atteints de lésion vérifiée par opération du ligament croisé antérieur et qui avaient subi une arthrographie Ils étudient la possibilité et l intérêt de la mise en évidence par arthrographie des lesions du ligament croisé antérieur

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ENCEPHALOGRAPHIC VENTRICULAR ATROPHY

Relationships between size of ventricular system and intellectual impairment

by

ROLAND NIELSEN, OLAF PETERSEN, P. THYGESEN and R. WILLANGER

The aims of the study have been (1) to investigate the ratio between the sizes of the different parts of the ventricular system in the various degrees of cerebral atrophy found in a selected group of neurologic patients in whom clinical assessment indicated more or less diffuse brain damage rather than localized, atrophic lesions and (2) to determine the relationship between individual and combined ventricular measurements and intellectual impairment, as assessed by psychologic tests.

No attempt was made to establish a normal material but instead a study was made of a 'broad spectrum' material of encephalograms which included, in addition to those of patients with normal ventricles, those with various degrees of cerebral atrophy in the established neuroradiologic meaning of the term.

The relation of cortical atrophy to ventricular atrophy and to intellectual impairment will be discussed in a subsequent paper.

Submitted for publication 17 August 1964.

The radiologic and psychologic investigations and recording of the results were performed concurrently without the radiologists and the psychologist being aware of each other s results

Previous investigations The evaluation of an encephalogram may be based upon a subjective impression or upon measurement, either linear or planimetric on the accepted view that there is a true relationship between measurements and degree of atrophy

Thorough anatomical studies have been performed by LAST & TOMPSETT (1953) and by KNUDSEN (1958) who demonstrated a correlation capricious it is true between certain linear ventricular measurements and the ventricular volume However, owing to radiographic distortion and agonal oedema these results can only be used with reservations in the assessment of the encephalogram

For obvious reasons a further difficulty is that only a few small 'normal series exist for comparison in clinical practice The basis for assessing the size of the ventricular system is therefore not particularly firm In addition the assessment involves a certain pseudo exactness which can presumably only be overcome by tomographic studies of the ventricular system, as suggested by e g KADRNKA (1963) The reason for our embarking upon this study, despite difficulties and misgivings was that a number of linear normal dimensions have been published and been fairly generally accepted, and that moreover we feel convinced of a certain correlation between variations in these ventricular measurements and the ventricular volume

As a 'normal standard of the width of the third ventricle a value below 6 mm (cf SCHIERSMANN (1952) NURNBERGER & SCHALTENBRAND (1955), and ANDERSEN et coll (1963)) was accepted Of their limited material, which owing to its selection can perhaps hardly be called 'normal, the last mentioned authors found 90 % to lie within this range DAVIDOFF & DYKE (1946) took 6 to 8 mm and SCHIFFER (1951) 7 mm as the upper limit of normal values SCHATZKI & TROLAND (1947) have reported a value of under 15 mm to be normal for the height of the lateral ventricles (cf Fig 1) which like ENGESET & LONNUM (1958) we have accepted JIROUT (1956) mentioned 15 to 16 mm

The present authors have also used the total transverse width of the cella media on both sides DAVIDOFF & DYKE (1946) gave 40 mm as the mean value, while BRUIJN (1959) felt that 40 mm must be the upper limit of the normal, we accepted the latter value ROBERTSON (1957) gave 44 mm BURHENNE & DAVIES (1963) 45 mm

The same standards have been employed for all age groups since, as emphasized particularly by LINDGREN (1954) radiologic knowledge of cerebral

age involution is deficient. HEINRICH LEIPZIG (1939) and BURHENNE & DAVIES found only slight age variations between the ages of 20 and 60. KNUDSEN in his normal post mortem series reported normal lateral ventricles in no less than 33 % of the 70 to 90 year group. Thus, even in the most advanced age groups the ventricular system does not constantly undergo dilatation but it may perhaps present a change in shape.

Some authors, for example LARSBY & LINDGREN (1940), EVANS (1942), MELCHIOR (1961), and ANDERSEN et coll. have assessed the lateral ventricles from the width of the anterior horns, either by direct measurement or by index determinations. That the present authors chose to measure the cella media, as did DAVIDOFF & DYKE (1946), was due to the fact that this part of the lateral ventricles is subjected to less radiographic distortion and, as stated by BULL (1960), is less variable and usually easier to define. The reason for not taking advantage of what appeared to be offered by index determinations for purposes of comparison, is that it was not felt that the index reflects a reality. As a matter of fact, it was demonstrated by VINKEN & STRACKEE (1960) that the width of the ventricles is remarkably constant despite advancing age, that the variation in cranial width exceeds the variation in ventricular width, and *that these variations are not concurrent*.

There have been publications, among others the retrospective studies of GOSLING (1955) and BURHENNE & DAVIES, dealing with the correlation between radiologic signs of cerebral atrophy and dementia. This subject has also been discussed by KIEV et coll. (1962). ENGESET & LONNUM (1958) have carried out studies on the working capacity of the patients included in their investigations of ventricular atrophy.

Measurement methods

Measurements on the encephalograms were performed by two radiologists (R. N. and O. P.), independently of each other, with subsequent coordination of the results.

The diagnosis of atrophy requires as much from radiologic techniques as the diagnosis of tumours, especially when basing the former on measurements of the ventricular system (cf. LINDGREN (1951), BENNETT (1952), and MULLER (1958)). The technique advocated by LINDGREN (1949) appears to be the best one for revealing anatomical details.

Air was injected by lumbar puncture under local anaesthesia. The exposures were made on a Schonander skull table (F.F.D. 70 cm) during slow, fractionated insufflation of 35 ml atmospheric air with aspiration of about 15 ml spinal fluid. In addition to the standard exposures, films were obtained with

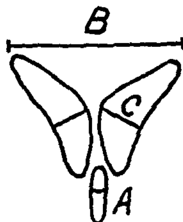


Fig 1 Ventricular measurements (on films with patient supine) A — maximum width of third ventricle B — width of right + left lateral ventricle C — height of lateral ventricles (shortest distance between the upper part medial wall of central part and the opposite wall)

an under table tube for the purpose of demonstrating cortical air During the exposures every effort was made to achieve uniform distribution of the air in the lateral ventricles The films were obtained immediately after the insufflation

The ventricular measurements are shown in Fig 1 and by arbitrary criteria were graded as follows

	A Width of third ventricle	B Width of right + left lateral ventricles	C Height of lateral ventricles (left + right)
No atrophy	<6 mm	<40 mm	<15 mm
Slight atrophy	6—8 mm	40—44 mm	15—16 mm
Moderate atrophy	9—11 mm	45—49 mm	17—18 mm
Severe atrophy	>12 mm	>50 mm	>19 mm

It was the aim to collect a group in which there was either diffuse cerebral atrophy or else no atrophy *in the selection of the patients* It was therefore found both expedient and justified to grade the atrophy by means of a combination of the ventricular measurements *involved in A B* and C above

Combined ventricular atrophy

IV — Severe according to at least 2 parameters irrespective of the third
III — Moderate

(a) Severe atrophy by at most 1 parameter irrespective of the others
(b) Moderate atrophy by 2 parameters *irrespective of the third*

II — Slight
- (a) Slight atrophy by 2 parameters and moderate by the third
- (b) Slight atrophy by 3 parameters
- (c) Slight atrophy by 2 parameters and none by the third
- (d) Moderate atrophy by 1 parameter, slight by 1, and none by 1
- (e) Moderate atrophy by 1 parameter, none by 2

I — None
- (a) *Slight atrophy by 1 parameter, none by 2*
- (b) No atrophy by 3 parameters

The following methods were used in the *psychologic* testing Goldstein Scheerer's cube test, items from Wais' block design test, Kasanin Hanfmann concept formation test, administered as a sorting test, digit span (auditory), digit learning (auditory), Ranschburg Wechsler — a test of paired associates administered to study learning and retention — and some tests for more specific cerebral dysfunctions which will be described in a subsequent paper

The psychologic investigation thus comprised three tests for what GOLDSTEIN et coll call abstract concrete capacity level and three tests of memory functions

The patients were divided into three broad intelligence groups on the basis of schooling, further education and interests (1) above normal, (2) normal, and (3) *below normal* Patients considered *to be subnormal were subjected* to intelligence tests

The results of the tests for intellectual impairment were graded according to predetermined criteria depending upon the intellectual level, by this means the patients were placed in one of the following groups

1 No intellectual impairment
2 Suspected, but uncertain intellectual impairment
3 Mild intellectual impairment
4 Mild to moderate intellectual impairment
5 Moderate to severe intellectual impairment
6 Severe intellectual impairment

Details of the comprehensive criteria used in the gradation of intellectual impairment will be given in a subsequent paper The factors registered have been those which can be scored with fair consistency, such as the time used for solution of problems, the number of problems not solved at one *step, the*

number of repetitions necessary for reproduction in the memorizing tests, and so forth

Consideration has been given in the grading to the fact that the present material comprises neurologic patients among whom there are fewer with severe intellectual impairment than would presumably be found in a group of psychiatric patients A preliminary pilot study in which the results of psychologic and radiologic investigations were compared has been used for guidance

Selection of the case material The principle was to deal only with stationary or progressive diffuse brain lesions of varied pathogenesis which were presumably irreversible and with patients whose neurologic diseases were presumed to be functional and in whom there was not necessarily any suggestion of organic brain lesions

The encephalographic evaluation of cerebral atrophy is undependable in children and apparent abnormalities, especially those found during the first years of life have often disappeared at a subsequent investigation (DURANT & SCAGLIOTTI 1951)

The material has therefore been restricted to adults

All patients over 18 years of age who underwent encephalography at the hospital during the period November 1960 to March 1963 were included regardless of the indication We excluded patients in whom the investigation, or supplementary investigations, e g cerebral angiography, disclosed neoplasm or haematoma, and patients in whom possible atrophy could be interpreted clinically or radiologically as being secondary to a localized lesion e g vascular malformation cerebral infarct or the like The principle of exclusion may have been arbitrary, especially in the case of cerebrovascular disease Patients whose encephalopathy was considered to be traumatic were included only if they had sustained their cranial injury more than one year previously Lastly patients were excluded if they were unable to cooperate in the psychologic testing

A total of 41 patients were excluded within the period named for the following reasons cerebral infarction 11, subdural or intracerebral haematoma 5 intracranial tumours 6 brain abscess 1 cranial injuries less than one year previously 8 lack of cooperation 3 psychologist unable to attend 7

Our case material thus comprised 300 patients of whom 185 were male It should be emphasized that almost 60 % (172 patients) had a working capacity normal for their age and occupation up to the time of their admission and that only 50 could be characterized as completely incapacitated The age distribution was as follows

	Cases
18—19 years	9
20—29 »	61
30—39 »	39
40—49 »	63
50—59 »	57
60—69 »	58
>70 »	13

Diagnostic grouping (the neurologic diagnostic criteria will be specified and discussed in a subsequent paper) was made according to following description

Traumatic cerebral disease (cranial injury with loss of consciousness + persisting post traumatic cerebral syndrome) 42

Arteriosclerotic brain disease (cerebral + extra cerebral criteria) 52

Presenile dementia (Pick Alzheimer type) 12

KZ syndrome (patients who were known to have suffered a loss of weight exceeding 35 % while prisoners in German concentration camps 1942—1945) 8

Presumed alcoholic brain damage 8

Cerebral sequelae of birth trauma 9

Cranial dys synostosis 2

Cryptogenic epilepsy, familial or non familial 25

Presumed symptomatic epilepsy (cause not demonstrated, but intra cranial neoplasm 'excluded) 18

Various 'functional' conditions (neuroses, hysterical, depressive, and asthenic states, hemicrania, etc) 52

Heterogeneous residual group (abiotrophy, *sequelae of poisoning*, etc) 20

'Cryptogenic atrophic encephalopathy' (cases in which atrophy of unknown origin, revealed by encephalography, has been accepted as the primary 'neurologic' diagnosis, and presumed to be the cause of, for example, epilepsy and various insufficiency states) 52

Results

Measured ventricular atrophies The results of the ventricular measurements and the combined grading of ventricular atrophy are given in Table 1 It will be seen that the measurements were technically practicable in 97 % The selected criteria place up to two thirds of the ventricular areas within the groups no + slight atrophy In 12 to 19 % the measurements revealed severe atrophy

Table 1

Degree of cerebral atrophy measured in the individual ventricular areas and that expressed by combined ventricular measurements

	Non	Slight	Moderate	Severe	Unassessable	Total
Width of 3rd ventricle	72 (24 %)	119 (39.7 %)	66 (22 %)	36 (12 %)	7 (2.3 %)	300
Width of r + l lateral ventricle	98 (32.7 %)	84 (28 %)	64 (21.3 %)	45 (15 %)	9 (3 %)	300
Height of l lateral ventricle	128 (42.7 %)	60 (20 %)	46 (15.3 %)	56 (18.7 %)	10 (3.3 %)	300
Height of r lateral ventricle	136 (45.3 %)	80 (26.7 %)	32 (10.7 %)	45 (15 %)	7 (2.3 %)	300
Combined ventricular atrophy	93 (31 %)	85 (28.3 %)	66 (22 %)	49 (16.3 %)	7 (2.3 %)	300

The third ventricles must be considered separately: relatively few (24 %) were classified as normal, and relatively few (12 %) as severely atrophic, the majority of the measurements (40 %) falling into the group of slightly atrophic.

The heights of the left and right ventricles were nearly the same but with a greater scatter of measurements for the left ventricle. This reflects the general experience that the ventricular system is usually larger in the dominant hemisphere. The heights differed from the other measurements in being normal in nearly half the cases, while this applied to only one quarter to one third of the other ventricular measurements.

The total transverse width of the lateral ventricles and the combined ventricular measurements gave practically identical grading.

Ratio of ventricular measurements. The broad third ventricle, in particular, has been used as an index of ventricular atrophy. In an attempt to investigate whether this is justified the size of the third ventricle has been compared with the total width and height of the lateral ventricles (Table 2).

The table reveals that there is an obvious correlation between the width of the third ventricle and the size of the lateral ventricles but the figures show an appreciable scatter. Since, as already mentioned, comparatively few severely atrophic third ventricles were encountered, the majority of the latter might primarily be expected to be combined with severely atrophic lateral ventricles. However, this in fact was true in only about half the cases. As to the other degrees of atrophy there was also some scatter, with representation beyond the immediate neighbour groups. The total width of the lateral

	Cases
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Table 2

Relation of third ventricle to the other ventricular areas

	Atrophy according to width of third ventricle									
	None		Slight		Moderate		Severe		Total	
Atrophy according to width of r. + l. lateral ventricle		(%)		(%)		(%)		(%)		(%)
None	52	(74.3)	37	(31.1)	6	(9.1)	3	(8.8)	98	(33.9)
Slight	15	(21.4)	46	(38.7)	22	(33.3)	1	(2.9)	84	(29.1)
Moderate	1	(1.4)	28	(23.5)	22	(33.3)	12	(35.3)	63	(21.8)
Severe	2	(2.9)	8	(6.7)	16	(24.2)	18	(53.0)	44	(15.2)
Assessable relations: total	70	(100)	119	(100)	66	(100)	34	(100)	289	(100)
Atrophy according to height of l. lateral ventricle		(%)		(%)		(%)		(%)		(%)
None	59	(85.5)	55	(46.2)	12	(18.2)	2	(5.7)	128	(44.3)
Slight	9	(13.1)	28	(23.5)	18	(27.3)	4	(11.4)	59	(20.4)
Moderate	1	(1.4)	26	(21.9)	14	(21.2)	5	(14.3)	46	(15.9)
Severe	0	(0.0)	10	(8.4)	22	(33.3)	24	(68.6)	56	(19.4)
Assessable relations: total	69	(100)	119	(100)	66	(100)	35	(100)	289	(100)
Atrophy according to height of r. lateral ventricle		(%)		(%)		(%)		(%)		(%)
None	60	(83.3)	59	(49.5)	15	(23.1)	2	(5.7)	136	(46.7)
Slight	12	(16.7)	39	(32.8)	23	(35.4)	5	(14.3)	79	(27.1)
Moderate	0	(0.0)	14	(11.8)	9	(13.8)	9	(25.7)	32	(11.0)
Severe	0	(0.0)	7	(5.7)	18	(27.7)	19	(54.3)	44	(15.2)
Assessable relations: total	72	(100)	119	(100)	65	(100)	35	(100)	291	(100)

ventricles thus indicated severe atrophy in 44 brains but in 10 of these the third ventricle was normal or only slightly atrophic.

Relation of ventricular size to age. The combined ventricular atrophy is distributed according to age in Table 3. The groups containing the youngest and oldest patients are small, whilst, apart from the group 30—39 years, each of the other groups contains about one sixth of the material.

Table 3

Combined ventricular atrophy in relation to age

	Age in years							
	18–19	20–29	30–39	40–49	50–59	60–69	>70	Total
Combined ventricular atrophy								
None	6	26	18	18	13	12	0	93
Slight	2	21	13	19	18	11	1	85
Moderate	1	10	5	17	14	17	2	66
Severe	0	3	3	6	11	17	9	49
Unassessable	0	1	0	3	1	1	1	7
Total	9	61	39	63	57	58	13	300
No + slight atrophy	90	78	79	62	55	41	8	61
Considerable atrophy	10	22	21	38	45	59	92	39

In 61 % of cases the ventricular systems were found to be normal or slightly atrophic in 39 % they were moderately or severely atrophic These two groups are compared on a percentage basis at the bottom of the table, *in the youngest* age group there were 90 % normal or slightly atrophic ventricular systems in the oldest only 8 %, *whilst there is a gradual transition* through the intermediate groups

The ventricular atrophies thus proved to be to some extent, a function of age In this selected neurologic series the atrophies of course manifest themselves earlier when age involution sets in (cf HEINRICH LEIPZIG 1939 and KNUDSEN 1958) Although atrophy *increases considerably* with advancing age there are even in the older age groups, a number of patients with normal or only *slightly atrophic* ventricular systems

Relation of ventricular size to intellectual impairment All ventricular measurements are compared with the results of the tests for intellectual *impairment* in Tables 4 to 8 (No impairment and doubtful impairment are combined)

It is apparent that no or only a mild intellectual impairment is in 73 to 80 % of cases combined with a normal or only slightly atrophic ventricular system With increasing ventricular atrophy there is an increasing incidence of intellectual impairment but the scatter is marked for instance, 22 to 29 % of the patients with severe ventricular atrophy had no or only slight intellectual impairment

Table 4

Width of third ventricle in relation to intellectual impairment (8 unassessable)

	Degree of atrophy				
	None	Slight	Moderate	Severe	Total
Intellectual impairment					
None	20	29	7	1	57
Mild	36	48	22	7	113
Mild — moderate	8	17	16	5	46
Moderate	3	10	10	9	32
Moderate — severe	3	12	5	6	26
Severe	1	2	6	9	18
No + mild impairment	79 %	65 %	44 %	22 %	57 %
> mild impairment	21 %	35 %	56 %	78 %	43 %

Table 5

Width of right + left lateral ventricle in relation to intellectual impairment (11 unassessable)

	Degree of atrophy				
	None	Slight	Moderate	Severe	Total
Intellectual impairment					
None	26	21	8	2	57
Mild	44	31	28	11	114
Mild — moderate	10	16	10	9	45
Moderate	6	7	7	10	30
Moderate — severe	7	5	6	7	25
Severe	3	4	5	6	18
No + mild impairment	73 %	62 %	56 %	29 %	59 %
> mild impairment	27 %	38 %	44 %	71 %	41 %

The correlation between ventricular atrophy and intellectual impairment is thus not immediately impressive, and a more detailed interpretation of correlations and discrepancies is difficult because of the unequal size of the groups

A simplified grouping of the degrees of intellectual impairment is compared, as a percentage, with various degrees of atrophy at the bottom of the five tables The width of the third ventricle and the height of the left lateral ventricle appear to be the individual measurements that correspond best with intellectual

Table 6

Height of left lateral ventricle in relation to intellectual impairment (11 unassessable)

	Degree of atrophy				
	None	Slight	Moderate	Severe	Total
Intellectual impairment					
None	41	12	2	2	57
Mild	60	20	19	14	11
Mild — moderate	14	14	9	8	45
Moderate	6	7	6	10	29
Moderate — severe	4	3	8	11	26
Severe	2	3	2	12	19
No + mild impairment	79	54	46	25 *	59
> mild impairment	21 *	46	54	75 *	41

Table 7

Height of right lateral ventricle in relation to intellectual impairment (9 unassessable)

	Degree of atrophy				
	None	Slight	Moderate	Severe	Total
Intellectual impairment					
None	43	10	3	1	57
Mild	56	32	14	11	113
Mild — moderate	17	20	4	5	46
Moderate	8	8	6	9	31
Moderate — severe	6	8	2	10	26
Severe	5	1	3	9	18
No + mild impairment	74 *	53	53	27	58 *
mild impairment	26 *	47	47 *	73	42 *

impairment — in both instances mainly in the extreme groups However the close correspondence between a *severe increase* in width of the third ventricle and the more severe forms of intellectual *impairment* is disturbed by the small size of the groups (cf Table 1) On the whole, *it is the* combined measurements for ventricular atrophy which show the best correlation with intellectual impairment (Table 8)

The correlation found (percentage of > slightly intellectually impaired persons in each of the groups of atrophy) is shown in relation to imaginary lines representing no and maximum correlation *in Fig* 2 Only slight differences

Table 8

Relation of combined ventricular measurements to intellectual impairment (9 unassessable)

	Degree of atrophy				
	None	Slight	Moderate	Severe	Total
Intellectual impairment					
None	28	23	5	1	57
Mild	46	31	26	11	114
Mild — moderate	8	17	13	8	46
Moderate	5	6	9	11	31
Moderate — severe	4	6	6	9	25
Severe	1	1	7	9	18
No + mild impairment	80 %	64 %	47 %	24 %	58 %
> mild impairment	20 %	36 %	53 %	76 %	42 %

have been found between the correlative values of the various measurements of ventricular atrophy *used in the present study. The best criteria are the height* of the left lateral ventricle and the combined ventricular measurements.

Discussion

Several factors may tend to render a grading of ventricular atrophy arbitrary, such as the radiographic technique, the sites measured in the encephalogram, the junction of the gradings for slight, moderate, and severe ventricular atrophy, and the selection of the case material.

We employed a uniform radiographic technique, realized the importance *of the slightest errors in projections, and during the procedure* endeavoured to obtain a uniform filling of the ventricles. As emphasized by LINDGREN (1951), the appearance of the lateral ventricles in the projection used is influenced not only by their volume but also by their shape. This applies only to the vertical extent of the ventricular system. A single tomographic section in the coronary plane, on a level with the foramen of Monro, the plane on which the investigations were based, might perhaps have overcome this difficulty. However, this could only have influenced one of the measurements, and it had to be disregarded, as the skull table was not adaptable for tomographic exposures.

Cases of localized ventricular atrophy may have escaped detection by the radiographic technique. This factor is probably counterbalanced by the clinical selection of the material. As already mentioned, we endeavoured to collect a

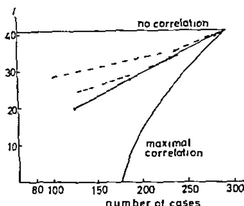


Fig 2 Cumulative percentages of patients with more than mild intellectual impairment shown for the degrees of atrophy in the individual ventricular areas calculated from $y = 100 \frac{x - 177}{x}$ The lines for no correlation and for maximum correlation are given for comparison
o—o—o—o width of right+left lateral ventricle
— — — — width of third ventricle
———— height of left lateral ventricle

broad spectrum group of patients without or with presumed diffuse cerebral lesions of various grades

It was decided to perform the measurements at sites where the ventricular system most constantly fills with air and where the two end points are well defined The floor or the lateral wall of the lateral ventricles was thus abandoned this criterion was also found by BURHENNE & DAVIES to be less well defined

It would have been less ambitious to choose — instead of the terms slight, moderate and severe ventricular atrophy — neutral designations e g A, B and C This would however have made the discussion of the practical aspects, especially the relation to intellectual impairment more abstract

The units of measurement and the designations were chosen and defined on the basis of the available patient material Patients from a department for chronic neurologic and psychiatric diseases would presumably have motivated another grading

The findings in the third ventricle exemplify the influence on the grouping of arbitrarily defined limits According to the chosen criteria, the third ventricle in the majority of brains is classified as slightly atrophic, whilst according to the criteria used for the other ventricles the majority of brains are considered to be normal This may be due to the relatively low normal value which we felt obliged to use for the third ventricle It is probable that 7 or 8 mm would have been more realistic values than 6 mm

In order to avoid an exaggerated influence of such, rather accidental, distinctions on the grouping an attempt was made to operate with a combination of several ventricular measurements According to this combined measurement an encephalogram was classified as normal even if one of the

Table 8

Relation of combined ventricular measurements to intellectual impairment (9 unassessable)

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	None	Slight	Moderate	Severe	Total
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None	28	23	5	1	57
Mild	16	31	26	11	114
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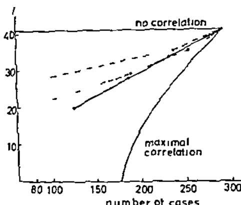


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ventricular areas showed slight atrophy, *providing that this atrophy was* isolated

Whether the present correlation between the ventricular atrophy and the *measured intellectual impairment is to be considered* good or poor depends upon what had been expected Another way in which the relationship between intellectual impairment and cerebral atrophy depend upon the arbitrary classification should be mentioned The highest percentage of patients with more than slight impairment is to be found in the ventricular parameter which delineates the smallest number with severe atrophy The third ventricle has the smallest number of patients in the most atrophic group and also, in accordance with what has just been stated, the highest percentage with more than slight impairment

The fewer patients delineated by a given measurement of severe atrophy, the closer is the expected relationship to intellectual impairment If thus, in the combined ventricular atrophy, we had demanded severe atrophy in all the three measurements described, instead of in two of them, then all the patients assigned to this group would have more than slight impairment, as opposed to 76 % *in the actual combined group* which was composed of patients with severe atrophy on two of the measurements The number in the former group is, however, only 15 whilst there are 49 in the latter

SUMMARY

A total of 300 neurologic patients presumed to have either no lesional brain damage or else a stationary or progressive diffuse brain lesion were submitted to encephalography and four different ventricular areas were measured There was some correlation between all the various measurements and an index of intellectual impairment obtained by psychologic tests

ZUSAMMENFASSUNG

Insgesamt *300 neurologische Patienten welche vermutlich keinerlei Hirnveränderung* oder möglicherweise eine stationäre oder progressive diffuse Veränderung hatten wurden enzephalographisch untersucht und die Ventrikelgrösse an vier Stellen gemessen Eine Beziehung zwischen den Massen und dem Index der intellektuellen Schädigung konnte mit psychologischen Methoden nachgewiesen werden

RÉSUMÉ

Les auteurs ont fait une encéphalographie à un total de 300 malades neurologiques supposés les uns n avoir aucune lésion cérébrale les autres une lésion cérébrale diffuse stationnaire ou progressive et *ont mesuré quatre parties différentes des ventricules* Ils ont trouvé une certaine corrélation entre ces diverses mesures et un indice de déficience intellectuelle basé sur des tests psychologiques

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FROM THE ROENTGEN DEPARTMENT (DIRECTOR PROF J FRIMANN DAHL) AND THE NEURORADIOLOGIC DEPARTMENT (DIRECTOR PER AMUNDSEN) OF ULLEVAL SYKEHUS OSLO NORWAY

HEIGHT OF FOURTH VENTRICLE IN NORMAL ENCEPHALOGRAMS

by

PER AMUNDSEN and OLE K GRIMSRUD

The conventional roentgenographic technique has been employed in most of the previously reported series of measurements of the fourth ventricle in encephalograms (DAVIDOFF & DYKE 1946 EPSTEIN 1950, ROBERTSON 1957, SUTTON 1950) and it would appear that few series in which tomography has been used routinely have been reported This latter technique has been employed in our hospital since 1958 and has generally been found sharply to delineate the fourth ventricle and render its exact measurements possible

Anatomy The fourth ventricle appears as a triangle in a lateral view The long rostral side usually called the floor is formed by the pons and the upper half of the medulla oblongata and is rhomboid in shape The dorsal wall or roof is formed by the anterior and the posterior medullary vela joining at a sharp angle (fastigium) The choroid plexus is attached to the posterior medullary velum The lateral recesses extend outwards from the lateral angles of the floor and two winglike extensions named by Retzius the superior posterior recesses pass caudad and dorsad from the lateral angles These

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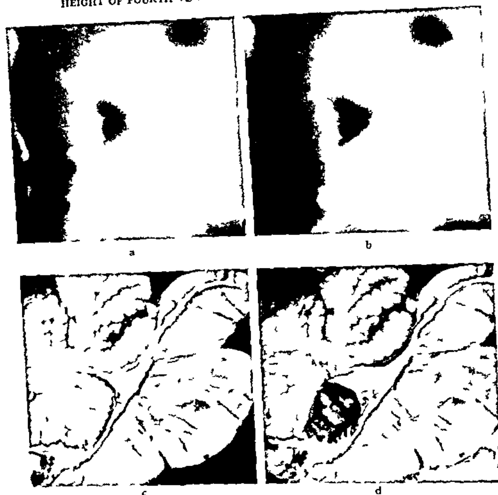


Fig 3 a) Midline section showing fastigium b) 0 5 cm to the right The superior posterior recess extends farther backwards than the fastigium c) Midline section through a preparation showing the fastigium comparable to (a) d) Cerebellum cut away showing the superior posterior recess (arrow)

for which they may be mistaken in lateral projections (Fig 2) Sufficiently thin tomographic sections will demonstrate however that the recesses are located laterally while the fastigium is normally situated in the midline (Fig 3)

The height of the fourth ventricle must obviously be measured from the fastigium and not from the superior posterior recesses It is usually possible to distinguish the fastigium even if the two recesses lie near the midline (Fig 4)



Fig. 1. a) Cast of the fourth ventricle. Arrow points to fastigium. b) Lateral roentgenogram of cast. A pin marks the fastigium; the superior posterior recesses extend more dorsally and caudally than the fastigium.

latter are situated on each side of the fastigium and usually extend dorsal to it; they are shown in a cast of the fourth ventricle in Fig. 1. These two recesses are often small but may also be relatively large. In survey films and even in 'thick' tomographic cuts, they are superimposed upon the fastigium,



Fig. 2. Lateral midline tomogram, thick cut with linear tomography. Fourth ventricle, fastigium ( ) (arrow) and superior posterior recesses (→→).

factor would be 1 17 The figure of 14 6 mm given by DAVIDOFF & DYKE, would thus be reduced to 12 5 mm which agrees well with the values of the present series EPSTEIN s figure of 16 mm corresponds to 13 7 mm SUTTON s figures which are almost identical with those of ROBERTSON vary between 13 and 21 mm equivalent to 11 1 and 17 9 mm

SUMMARY

The height of the fourth ventricle has been measured in 100 encephalographies in which tomography has been used as a routine In cases with no evidence of cerebral abnormality it was found to be 12 5 mm no significant variations with sex and age were observed

ZUSAMMENFASSUNG

Die Höhe des vierten Ventrikels wurde auf tomographischen Filmen von 100 Patienten ermittelt Die Höhe des vierten Ventrikels wurde in normalen Fallen auf 12 5 mm festgelegt es gibt keine nennenswerte Abweichungen durch Alter oder Geschlecht

RÉSUMÉ

La hauteur du quatrième ventricule a été mesurée sur 100 encéphalographies ou la tomographie a été systématiquement employée Elle est de 12 5 mm dans les cas ou il n y a pas de signe d affection cérébrale On n a pas constaté de variation significative avec l âge ou le sexe

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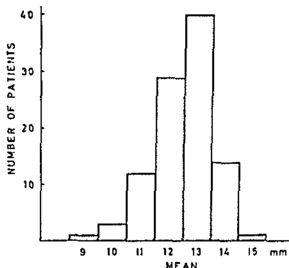


Fig. 4. Distribution of measurements of the height of the fourth ventricle in 100 cases (reduced to true size). Mean 12.5 mm. 1 standard deviation = 1.14.

Material and Method. All the lumbar encephalographies were performed with the patient sitting. The passage of air was controlled with sagittal tomograms in the midline and 1 to 2 cm to each side during the fractional injection. It will generally be found possible from the series obtained by this method, to select at least one or two films suitable for measurements of the fourth ventricle.

The aim was to study the height of the normal fourth ventricle. An entirely normal material cannot be obtained since there will always be an indication for the examination. The material was therefore selected in the following way. A number of encephalographies, all of which had been interpreted as normal and in which at least one tomogram demonstrated the fourth ventricle clearly, were examined. All the cases had been admitted for investigation, which included as a minimum a full neurologic, including CSF, examination and electroencephalography. A clinical follow up was often available. The clinical records were all reviewed and re-evaluated by a neurologist, (P. DIETRICHSON), and only such cases were included in which no evidence of any significant abnormality of the brain could be detected. A hundred cases, as close to normal as it is possible to reach, were thus collected.

The height of the fourth ventricle was measured from the fastigium to the floor and reduced to the true size after the magnification due to distortion had been calculated. The size varied between 9 mm and 15 mm, with a mean of 12.5 mm (Fig. 4) and was unchanged by sex and age.

It would appear that the previously reported figures were given as direct measurements on the film. If the FFD was, for example, 75 cm and the distance from the midsagittal plane to the film was 11 cm, then the magnification

factor would be 1 17 The figure of 14 6 mm given by DAVIDOFF & DYKE, would thus be reduced to 12 5 mm which agrees well with the values of the present series EPSTEIN s figure of 16 mm corresponds to 13 7 mm SUTTON s figures which are almost identical with those of ROBERTSON vary between 13 and 21 mm equivalent to 11 1 and 17 9 mm

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La hauteur du quatrieme ventricule a été mesurée sur 100 encéphalographies ou la tomographie a été systématiquement employée Elle est de 12 5 mm dans les cas ou il n y a pas de signe d affection cérébrale On n a pas constaté de variation significative avec l age ou le sexe

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FROM THE DEPARTMENT OF RADIOLOGY (DIRECTOR KRISTIAN OVERGAARD), CITY AND COUNTY HOSPITAL, VIBORG, DENMARK

PYELOVENOUS BACKFLOW AND HEMATURIA

by

KRISTIAN OVERGAARD

Pyelovenous backflow is frequently observed. One special type, so called pyelo canalicular backflow, in which the contrast medium fills the intact collecting tubes of the pyramids, differs from the others and may not be a manifestation of morbidity. The types termed pyelo sinous, pyelo lymphatic and pyelo venous ingression are, however, indications of progressive stages of disruption of the continuity of the renal fornices, with contrast infiltration into the surrounding connective tissue and secondary ingress into the lymphatic vessels and veins.

Following injury of the mucous membrane, the contrast medium may penetrate a few millimetres into the connective tissue; it may then appear in the roentgenograms sometimes only as small horn shaped accumulations, more or less diffuse, or sometimes as large and irregular stratifications from the fornix, most frequently forming the so called arcades. Under certain conditions the wall of a vein may be injured and an indirect connection may be opened up between the renal pelvis and the venous system. The contrast medium may pass from the sinus tissue via the lymph tracts and the cisterna chyli to the thoracic duct and thus into the blood (OLSSON 1948, PERSKY, BONTE & HUBAY 1957). The roentgen appearances of the initial contrast infiltrations are

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a b

Fig 1 Five days history of marked hematuria and moderate pain in right loin a) Urography b) Pyelography (3 days later) Both examinations revealed a small sinous extravasation at a lateral calyx in the right kidney (arrows) Clinical examination (including tb culture) normal

characteristic but unfortunately similar appearances may be met with in the early stages of tuberculosis pyelonephritic processes and papillary necrosis The clinical aspects and the subsequent course will be the only guides to the true condition

After roentgenologic demonstration of backflow (ZACHRISSON 1911 HINMAN & LEE BROWN 1924) many authors have tried to ascertain the conditions determining the evolution of the phenomenon It appears that backflow takes place through a small injury of a fornix A sharp fornix represents a condition in this evolution but the fibrous and blunt fornices that are seen in chronic hydronephrosis are not injured in this way the injuries seem to arise as a result of elevation of the intrapelvic pressure most frequently to between 50 and 80 mm Hg Extended knowledge of the pathology of the different forms of backflow has thus been obtained (see also FUCHS 1931)

These conceptions have in the main been confirmed The technical difficulties in measuring the intrapelvic pressure in man have however, lead to some doubts regarding the importance of this factor Still it is probably certain that contractions of the musculature of the renal pelvis may produce fluctuations in pressure and several observations have indicated that occlusion of the ureter

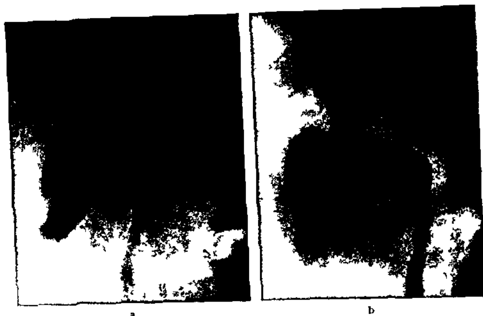


Fig. 2. Six months history of several slight attacks of left loin pain lasting about an hour and accompanied by slight hematuria. a) Urography. b) Pyelography (4 days later). Both examinations revealed a slight pyelo sinous extravasation at a left lower calyx and a small outflow at the lateral calyx. Clinical examination (including tb culture) normal. (No abnormality was evident at a repeat examination a little less than 3 years later.)

may raise the intrapelvic pressure to the danger level. Backflow may be directly demonstrated by urography during acute ureteric occlusion caused by stones (LINDBOM 1943, OLSSON 1948). It may also be produced by intentional occlusion of the ureteric orifice with a catheter (NARATH 1951), similar effects are well known from animal experiments (e. g. FUCHS).

Forced contrast filling by retrograde pyelography may possibly under certain circumstances produce a backflow of this order but the presence of the catheter itself in the ureter may occasionally produce spasm and lead to complete ureteric occlusion and increase the intrapelvic pressure. Backflow is commonly manifest by renal hemorrhage and colic and sometimes by more serious general signs. The frequency of backflow in retrograde pyelography was reported by RUMMELHARDT (1951) to be 13 % (125 out of 960 cases) and by KOHLER (1953) to be 25 % (154 out of 628 cases).

Several examinations of the evolution of hydronephrosis by total occlusion of the ureter have revealed minor epithelial defects at the fornices and hemor-



a b

Fig 3 Six months history of several bouts of frank hematuria accompanied by moderate pain in the right loin lasting up to a day a) Urography b) Pyelography (4 weeks later) Both examinations revealed extensive pyelo-venous infiltration at the superior left calyx Clinical examination (including tb culture) normal

rhage into the pelvis (e g FUCHS) These also have disclosed resorption of the pelvic contents apparently mainly through the lymph tracts, into the blood circulation though no backflow was directly proved it is reasonable to assume that it must have occurred (e g RISHOLM & ÖBRINK 1958 PERSKY BONTE & HUBAY 1957 MYINT & MURPHY 1957, FUCHS)

Though it is generally acknowledged that backflow is a manifestation of an open lesion of a fornix few studies of its further development seem to have been made NARATH (1951) stated that when the ureter was intentionally occluded in a repeat examination backflow was not reproduced at the same fornix and concluded that this was due to fornical absorption rather than to a laesio continui

Present investigations

The author has sometimes observed that a small backflow disclosed at urography or pyelography may be present in the same site and be of same size and appearance at a repeat examination performed after an interval of a few days weeks or even months (Figs 1 to 3) This seems to indicate that the injured



Fig. 4. Severe acute left renal colic. Urography during the attack revealed massive left-sided urostasis above a high ureteric stone complicated by pyelo-sinous outflow

area through which the medium passed was either not healed at the second examination or that at the site of backflow the wall was less resistant than in other places.

For many years we regarded it remarkable that backflow at pyelography appeared most frequently in certain diseases. An examination of our registered cases of backflow from the period 1953—1960 disclosed that backflow appeared in 51 cases out of a total of 118 pyelographic examinations. Only marked changes were recorded, and presumably slight signs were overlooked or not noted. These backflows are not evenly distributed over the total material examined, in which is included a considerable number of gynaecologic cases as well as various cases of obstruction of the upper and lower urinary tract. They practically occur only in certain groups of disease which are characterized by inflammatory conditions of the pelvis or renal colic and/or haemorrhage, as may be seen from Table 1. Similar observations have been made by RUMMELHARDT, and by TAKAHASHI.

Discussion of results

A thorough examination of all our pyelographies (a total of 53) during the year 1960 revealed signs of backflow in 26. The majority of these were indicated by slight but characteristic small infiltrations around the fornices

Table 1

Distribution of disease in registered backflow (51 cases) during pyelographic examinations (a total of 448) performed in the period 1953—1960

	Backflow
Renal tuberculosis	3
Chronic pyelonephritis	13
Occluding renal and ureteric calculi	7
Non-occluding renal and ureteric calculi	4
Pyelotomiae sequelae	2
Renal colic without verified calculi and without verified hematuria	4
Renal colic without verified calculi but with verified hematuria	4
Essential hematuria	14

The distribution in relation to disease is the same as the one found in the earlier material (cf Tables 1 and 2)

Pyelography was in these cases performed by cautious manual injection this method has been supplanted during recent years and now bilateral pyelography is carried out by the intermittent injection of the contrast medium on the side of the probable disease at a maximum pressure of 60 cm H_2O The reduction in pressure by the narrow catheter and the relatively free outflow from the pelvis down the ureter along the catheter seem to prevent any possibility of the injection building up hydrostatic pressure increase in the renal pelvis This assumption has been verified in a number of cases by direct measurement of the pressure with an Elema electrical manometer The pressure in the renal pelvis was fairly constant though showing peristaltic movements in individual cases before as well as during the injection The pressure varied somewhat from one case to another, however from about 1 to about 20 mm Hg This is in agreement with the findings of KIIL (1957) and of MYINT & MURPHY (1957) Only in one single case (one of backflow previously proved) was an intrapelvic pressure of about 80 mm Hg recorded during a short attack of colic a further sinous backflow then occurred around another fornix

The perfusion of contrast medium on the affected side takes an hour and generally results in good filling of the pelvis as the medium is mixed with the urine excreted The urine from the contralateral side is collected (1) before the beginning of the installation and (2) during the hour of installation and the iodine concentration in both samples is measured the examination is then concluded by manual injection of this renal pelvis



Fig. 4. Severe acute left renal colic. Urography during the attack revealed massive left sided urostasis above a high ureteric stone complicated by pyelo sinous outflow.

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Table 3

Comparison of distribution of disease and occurrence of backflow in cases with or without hematuria in a material of 71 pyelographic examinations carried out with a special technique

	Number of examinations			Chemically verified backflow			Without chemically verified backflow
	Total	With hematuria	Without hematuria	Total	With roentgenol backflow	Without roentgenol backflow	
Renal tumour	4	3	1	2	1	1	2
Hydronephrosis	2	1	1	2	1	1	
Cystic kidney	1		1				1
Chronic pyelonephritis including papillary necrosis	24	6	18	18	14	4	6
Renal calculi	3	2	1	2	1	1	1
Ureteric calculi	9	4	5	6	5	1	3
Renal colic without obvious calculi	2	1	1	2	2		
Essential hematuria	16	16		14	13	1	2*
Varied abdominal diseases (without catheter spasm)	7		7				7
Varied abdominal diseases (with catheter spasm)	2		2	2	2		
Lesion of pelvic fornices	1		1	1	1		

* In one case heavy backflow occurred in the contralateral kidney

ally under 0 06 °/₀₀ depending among other things on the time that had elapsed since the previous excretion urography As the iodine value may be influenced for example by various drugs all cases with initial values *higher than 0 08* °/₀₀ were excluded in our selection of material for study

The iodine concentration of the urine was in 22 cases almost unchanged in the first and second urine samples *and never amounted* to more than 0 1 °/₀₀ in either In 49 cases a distinct *increase* in the iodine concentration occurred during the examination, and in all of these the final concentration was at least 0 5 °/₀₀ in 19 it was more than 1 °/₀₀ and in 11 more than 2 °/₀₀ The maximum value measured amounted to 7 07 °/₀₀ iodine concentration, which produced a visible urogram on the contralateral side

To explain this finding we assume that in the first group of cases a small absorption of contrast medium had taken place from the mucous membrane of the renal pelvis and bladder whereas in the second group there was also a

Table 2

Distribution of disease in a material of 53 consecutive pyelographies performed during 1960

	Number of pyelographic examinations	Backflow registered roentgenologically
Renal tuberculosis	1	1
» tumor	2	1
Chronic pyelonephritis	13	5
Renal and ureteric calculi	11	7
» colic without obvious calculi	1	0
Essential hematuria	11	11
Hydronephrosis	3	0
Prostatic hypertrophy	3	1
Various conditions	8	0
Totals	53	26

As this technique excludes increase in intrapelvic pressure due to contrast filling, no lesions of the pelvic wall will develop. The relatively protracted filling of the pelvis makes it possible, however, if defects are present in the pelvic fornices, that the contents may leak out to the surrounding sinus tissue, slight pyelo-sinous backflow, in most cases demonstrable in the films, may then result. The contrast medium will be resorbed through the lymphatic tracts, then reach the blood circulation and again be excreted in the urine through both kidneys so that some of it will appear in the samples from the contralateral kidney. A moderate resorption of the medium from the epithelium of the pelvis and bladder may also take place, and little importance can therefore be attached to a small increase in the iodine concentration. The method is based on a physiologic concentration of the contrast medium itself and is about a hundred times more sensitive than the fluorescein method described by OLSSON (1948). In conditions such as now discussed it fully comes up to the methods based on radioactive tracer substances (RISHOLM & ÖBRINK 1958).

The technique aims at providing an objective proof that the small stratifications and sinous extravasations observed are the result of extrapelvic extravasation as well as at proving the presence of extravasation in cases in which the changes are too small to be demonstrated with certainty in films.

We have now performed 71 pyelographic examinations with this technique if we discount a number of examinations that were technically deficient or otherwise unsuitable. The initial iodine concentration in the urine was gener-

Hematuria attending ureteric stones is generally understood to be the result of a mechanical injury of the ureter caused by the concrement The proof of backflow produced by urography during acute colic (LINDBOM 1943 OLSSON 1948 and Fig 4) suggests however, that marked hemorrhage may be due to rupture of a fornix and backflow

SUMMARY

An investigation into the causes of pyelo-venous backflow in a series of 71 pyelographic examinations by means of a special technique is described The total material reviewed consist d of 572 cases The author suggests that pyelo-venous backflow most probably is caused either by inflammatory lesions in the renal pelvis or by disease in which renal colics and/or hemorrhage are the dominant symptoms It is nearly always present in cases of essential hematuria

ZUSAMMENFASSUNG

Es wird die Ursache des pyelovenosen Ruckflusses an einer Serie von 71 pyelographischen Untersuchungen mittels einer Spezialmethode beschrieben Das durchgesehene Gesamtmaterial umfasste 572 Falle Der Verfasser vermutet dass der pyelovenose Ruckfluss hochstwahrscheinlich durch entzundliche Schaden in den Nierenbecken oder durch Erkrankungen mit Nierenkolik und/oder Blutungen verursacht wird Der Ruckfluss ist fast immer in Fall n von essentieller Hamaturie vorhanden

RÉSUMÉ

Présentation d une recherche de la cause du reflux pyélo-veineux sur une *série de 71* examens pyélographiques par une technique spéciale Le nombre total des cas *passés en* revue est de 572 L auteur pense que le reflux pyélo veineux est tres probablement causé soit par des lésions inflammatoires du bassinet renal soit par *une affection* ou les coliques néphrétiques et/ou l hémorragie sont les symptomes dominants Ce reflux existe presque toujours dans les cas d hématurie essentielle

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defect in the wall of the renal pelvis through which the medium produced greater or smaller backflow with subsequent resorption

The roentgenologic findings are fully in accord, as no backflow could be revealed in anyone case in the first group whereas 40 cases in the second group presented evidence of significant backflows (mainly sinous) and several of the remaining showed uncertain changes, there was also fair agreement between the size of the backflow and the increase in iodine concentration

The distribution of the changes occurring in the cases examined are apparent from Table 3 which also indicates any recent history of hematuria By comparison of the three columns it is clear that backflow mainly occurs in disease in which open injuries to the renal pelvis must be expected (tumour, tuberculosis and chronic pyelonephritis incl papillary necrosis) or by lesions in which renal hemorrhage and colics are frequent or the dominating symptoms

There will also be some cases in which reflux occurs as a technical complication brought about by spasm of the ureter and pelvis as a result of the catheterization and contrast injection

Conclusions

Of the groups quoted the cases of essential hematuria are of special interest in the present context This group includes all cases of hematuria, frequently intermittent, in which a thorough clinical investigation gave no indication of the source of hemorrhage Retrograde pyelography shortly after the hemorrhage almost constantly revealed signs of reflux As the development of a lesion of the fornix is very unlikely with the technique described, it may be presumed that these visible (or only chemically demonstrable) pyelo sinous fillings must be otherwise explained It could be that either an open fornical lesion, or at least increased vulnerability that could easily lead to fornical rupture, were present before the actual examination As it is a matter of general experience that renal bleeding is fairly constant following pyelographic backflow, and as it is probable that the healing of the fornical lesions will take some time, the most reasonable explanation of the facts mentioned may be that a hitherto unknown factor causes spasm to occur in the renal pelvis and ureter, leading to pyelo sinous backflow in fair analogy with the backflow that may be observed during pyelography or urography in cases of ureteric stones Furthermore, the majority of cases of essential hematuria have some history of pain or colic of a renal type, before or accompanying the hematuria

This assumption is further supported by a small number of pathologico anatomical reports of fornical rupture in cases of hematuria (CEELEN 1930, FUCHS 1931, FLOHE 1947)

Hematuria attending ureteric stones is generally understood to be the result of a mechanical injury of the ureter caused by the concrement The proof of backflow produced by urography during acute colic (LINDBOM 1943, OLSSON 1948 and Fig 4) suggests, however that marked hemorrhage may be due to rupture of a fornix and backflow

SUMMARY

An investigation into the causes of pyelo-venous backflow in a series of 71 pyelographic examinations by means of a special technique is described The total material reviewed consisted of 572 cases The author suggests that pyelo-venous backflow most probably is caused either by inflammatory lesions in the renal pelvis or by disease in which renal colics and/or hemorrhage are the dominant symptoms It is nearly always present in cases of essential hematuria

ZUSAMMENFASSUNG

Es wird die Ursache des pyelovenosen Ruckflusses an einer Serie von 71 pyelographischen Untersuchungen mittels einer Spezialmethode beschrieben Das durchgesehene Gesamtmaterial umfasste 572 Falle Der Verfasser vermutet dass der pyelovenose Ruckfluss hochstwahrscheinlich durch entzundliche Schaden in den Nierenbecken oder durch Erkrankung n mit Nierenkolik und oder Blutungen verursacht wird Der Ruckfluss ist fast immer in Fallen von essentieller Hamaturie vorhanden

RÉSUMÉ

Présentation d une recherche de la cause du reflux pyélo-veineux sur une série de 71 examens pyélographiques par une technique spéciale *Le nombre total des* cas passes en revue est de 572 L auteur pense que le reflux pyélo veineux est tres probablement causé soit par des lésions inflammatoires du bassinet rénal *soit par une affection* ou les coliques néphrétiques et/ou l hémorragie sont les symptomes dominants Ce reflux existe presque toujours dans les cas d hématurie essentielle

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NORMAL VARIATIONS IN ANATOMY, CONDYLAR MOVEMENTS, AND ARTHROSIS FREQUENCY OF THE TEMPOROMANDIBULAR JOINTS

by

BENT MADSEN

Roentgen examination of the temporomandibular joints is a common procedure and constitutes about 0 5 % of the total number of examinations carried out in our department in the Danish Central hospitals the correspond ing figure is 0 3 %

Various radiographic techniques with special projections (LINDBLOM 1960) tomography (RICKITTS 1950), and arthrography (NØRGAARD 1947), have been developed to obtain improved results

Studies of the morphologic factors and the function of the temporomandibular joints have been carried out by RICKITTS and by MELOT & JEANMART MICHEZ (1961) based on tomography, and by LINDBLOM with a special technique The results of these investigations cannot however, be directly transposed to the standard method that would appear to be the one still most widely used the one of obtaining lateral roentgenograms with a projection similar to that proposed by Schuller for the examination of the temporal bone

We therefore started an investigation with a view to study with the aid of

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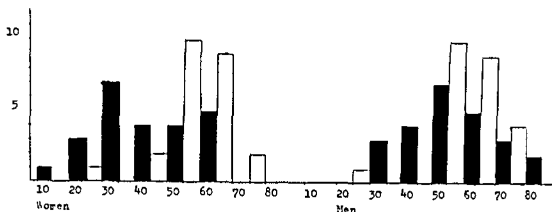


Fig. 1. Age distribution in the material: patients without dentures (black columns) and with dentures (white columns).

this standard method, the values of the joint parameters and condylar movements, when the mouth is opened, and further, with a view to determine the incidence of arthrosis in a normal material and to compare this with the clinical and radiologic findings. The influence on the radiographic quality of varying the positioning has also been carefully assessed.

The *material* consisted of patients who had never experienced symptoms referable to the temporomandibular joints and comprised 48 women and 48 men, making a total of 192 temporomandibular joints. The ages of the women were between 17 and 74 years and of the men between 23 and 90 years. Half the number of patients in each one of the two sex groups had had upper, or upper as well as lower, dentures for from 7 to 53 years. The age distribution in the four groups thus obtained is shown in Fig. 1. No further grouping in relation to dental conditions or malocclusions was attempted since such information is usually not available to the radiologist.

Radiographic data. A Lysholm skull table was used, FFD 70 cm, the central ray being angled 25° caudally towards the joint examined, the patient was lying prone with the head sideways and the mid sagittal plane of the skull parallel to the film. The examinations were carried out in normal occlusion as well as with the mouth as wide open as possible.

Anatomical measurements

All the measurements were performed directly on the roentgenograms, the technique is illustrated in Fig. 2. A line drawn from the petrotympanic fissure and touching the upper part of the articular eminence was chosen as reference line.

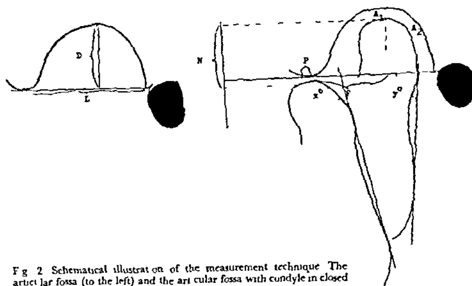


Fig 2 Schematical illustration of the measurement technique The articular fossa (to the left) and the articular fossa with condyle in closed and open positions (to the right)

The depth of the articular fossa (D) is the greatest distance between the reference line and the bottom of the fossa The length of the fossa (L) is the distance between the petrotympanic fissure and the upper part of the articular eminence The interarticular space is the shortest distance between the upper surface of the condyle and the bottom of the articular fossa (A_1) and the shortest distance between the condyle and the posterior surface of the fossa (A_2)

The condylar position was registered as normo antero- or retro-position, when the condyle in occlusion was placed either centrally or in the anterior or posterior part of the articular fossa

All the values have been recorded graphically to assure a balanced distribution Only the values on the length of the fossa (L) showed slightly increased dispersion towards higher values Ordinary statistical formulas were used throughout and statistical significance was considered to occur if $P < 0.01$

The values of D L A_1 and A_2 are given in *Table 1* The values are slightly smaller in women than in men, this difference is statistically significant for the fossal parameters but not for the interarticular space This is in contradiction to the observations of LINDBLOM who observed no difference between the mean values for the two sexes The value of the right and left temporomandibular joints are the same

The condylar position in occlusion is given in Table 2 The most common

Table 1

Measurement values of the joint parameters mean +/—error, standard deviations, and number of cases (within parentheses)

Para meter	Sex	Right side	Left side
D	Men	8 02 +/— 0 16 1 13 (48)	7 97 +/— 0 17 1 17 (48)
	Women	6 98 +/— 0 12 0 81 (48)	7 08 +/— 0 11 0 75 (48)
L	Men	20 18 +/— 0 33 2 29 (48)	20 52 +/— 0 35 2 43 (48)
	Women	19 14 +/— 0 22 1 50 (48)	19 14 +/— 0 25 1 73 (48)
A_1	Men	2 39 +/— 0 13 0 91 (48)	2 52 +/— 0 17 1 17 (48)
	Women	1 97 +/— 0 10 0 72 (48)	2 22 +/— 0 13 0 91 (48)
A_2	Men	1 82 +/— 0 13 0 88 (48)	1 83 +/— 0 15 1 06 (48)
	Women	1 46 +/— 0 11 0 74 (48)	1 58 +/— 0 12 0 85 (48)

finding is normo position Among the men, antero position occurs more often than retro position, and the reverse is true among the women

Measurements of condylar movements

Only condylar displacements in the sagittal plane, from the occluded to the maximal open position, were studied The technical procedure is illustrated in Fig 2

The forward movement (F) of the superior aspect of the condyle is measured in relation to the reference line, the downward displacement (N) of the same point being measured upon a line perpendicular to the reference line The position of the superior aspect of the condyle in relation to the upper part of the articular eminence after opening (P) has also been noted Finally, the opening angle of the condyle is defined as the difference between the angle of the ramus tangent to the reference line in the open and occluded positions ($x° — y° = V°$)

The values of N, which are given in Table 3, do not *really give a satisfactory* impression of condylar movement The highest values will be found when the

Table 2

Condylar position in occlusion

Men	Right side	Left side
Normo-position	35 (72 9)	32 (66 7)
Antero-pos tion	9 (18 8)	11 (22 9)
Retro-pos tion	4 (8 3)	5 (10 4)
Women		
Normo pos tion	34 (70 8)	34 (70 8)
Antero-position	4 (8 3)	3 (6.2)
Retro-position	10 (20 5)	11 (22 9)

condyle lies at the upper part of the articular eminence diminishing in positions in front of as well as behind this point The right and left values are similar but an intersexual difference, corresponding to the earlier mentioned difference between the two sexes in depth of the fossa and thus difference in height of the articular eminence is evident

Forward displacement of the condyle is determined by the values of F and P which are shown in Tables 4 and 5 The latter of these measuring methods is considered to be the more useful as the results are less dependent on anatomical variations The condyle generally moves to, or in front of the superior aspect of the articular eminence but from the figures in Table 5 it is not possible to determine the transition from normal to reduced mobility However, by making comparisons between the single cases throughout the material it was found that in those with definitely reduced mobility the open condylar position was 4 mm or more behind the superior aspect of the articular eminence and in doubtful cases 3 mm behind the eminence Eight women and 14 men were found to have reduced mobility of the temporomandibular joint

Table 3

Measurement values of condylar downward displacement (V) mean +/− error standard deviations and number of cases (within parentheses)

	Right side	Left side
Men	6 04 +/− 0 23 1 58 (48)	6 15 +/− 0 26 1 82 (48)
Women	5 71 +/− 0 26 1 80 (48)	5 73 +/− 0 27 1 87 (48)

Table 4

Measurement values of forward movement of condyle (F) mean +/− error, standard deviations and number of cases (within parentheses)

	Right side	Left side
Men	11 60 +/— 0 69 4 78 (48)	12 92 +/— 0 63 4 36 (48)
Women	12 02 +/— 0 74 5 09 (48)	13 06 +/— 0 60 4 12 (48)

Table 5

Position of condyle in relation to articular eminence after opening of the mouth

Men			
Right side			
In front of	21 patients	(43 75 %)	1—8 mm
Above	5 —	(10 42 %)	0 mm
Behind	22 —	(45 83 %)	1—10 mm
Mean			— 0 21 mm
Left side			
In front of	26 patients	(54 17 %)	1—11 mm
Above	4 —	(8 33 %)	0 mm
Behind	18 —	(37 50 %)	1—9 mm
Mean			+ 1 65 mm
Women			
Right side			
In front of	25 patients	(52 08 %)	1—12 mm
Above	3 —	(6 25 %)	0 mm
Behind	20 —	(41 66 %)	1—11 mm
Mean			+ 0 54 mm
Left side			
In front of	32 patients	(66 66 %)	1—11 mm
Above	6 —	(12 50 %)	0 mm
Behind	10 —	(20 84 %)	1—10 mm
Mean			+ 2 15 mm

Table 6

Measurements of opening angle of the condyle (I) the values being mean +/− error standard deviations and number of cases (within parentheses)

	Right side	Left side
Men	19 73 +/— 0 83 5 55 (45)	18 71 +/— 1 06 7 11 (45)
Women	19 15 +/— 1 04 7 23 (48)	19 42 +/— 0 83 5 71 (47)

Table 7

Arthrosis assessed radiographically on the basis of primary and secondary findings

	Number of cases	
	Right	Left
Primary findings		
Reduced interarticular space	5	7
Irregular articular surfaces	2	2
Marginal proliferations	1	0
Sclerosis of articular surfaces	1	0
Subchondral cysts	1	1
Secondary findings		
Reduced mobility	3	2
Possible reduced mobility	2	0
Retro-position	3	4
Antero-position	1	0
Total number of patients	9 (9 4 %)	8 (8 3 %)
Women	4	4
Men	5	4
Patients with dentures	6	2
Patients without dentures	3	6

Unilateral findings 9 patients
Bilateral findings 4 patients
Total numbers 13 patients (13 5 %)
Mean age 63 2 years

on the right side but only 3 women and 7 men were found to have reduced mobility on the left side This might explain why the values of F and P are slightly greater among the women and why the values on the left side are the greatest in both groups The opening angle of the condyle (V), which is registered in Table 6 presents no differences in relation to side or sex

Radiologic and clinical evaluations of the temporomandibular joints

The changes determined by radiographic as well as by clinical examination were assessed and the results obtained by the two methods of examination were compared

The *radiographic* findings indicating arthrosis (reduced interarticular space, irregular articular surfaces marginal proliferations, sclerosis of the articular surfaces subchondral cysts) have been termed primary while findings of more

Table 4

Measurement values of forward movement of condyle (F) mean +/− error, standard deviations and number of cases (within parentheses)

	Right side	Left side
Men	11 60 +/—0 69 4 78 (48)	12 92 +/—0 63 4 36 (48)
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Above	4 —	(8 33 %)	0 mm
Behind	18 —	(37 50 %)	1—9 mm
Mean			+ 1 65 mm
Women			
Right side			
In front of	25 patients	(52 08 %)	1—12 mm
Above	3 —	(6 25 %)	0 mm
Behind	20 —	(41 66 %)	1—11 mm
Mean			+ 0 51 mm
Left side			
In front of	32 patients	(66 66 %)	1—11 mm
Above	6 —	(12 50 %)	0 mm
Behind	10 —	(20 84 %)	1—10 mm
Mean			+ 2 15 mm

Table 6

Measurements of opening angle of the condyle (V) the values being mean +/— error standard deviations and number of cases (within parentheses)

	Right side	Left side
Men	19 73 +/—0 83 5 55 (45)	18 71 +/—1 06 7 11 (45)
Women	19 15 +/—1 01 7 23 (48)	19 12 +/—0 83 5 71 (47)

Table 9

Observations made in the clinical examinations

	Number of cases	
	Right	Left
Crepitation	5	3
Clicking	6	10
Tenderness	2	2
Capsular swelling	1	2
Reduced hinge movement	3	5
Reduced gliding movement	5	4
Total number of patients	16 (16 7)	20 (20 8)
Women	8	11
Men	8	9
Patients with dentures	11	12
Patients without dentures	5	8

Unilateral findings 8 patients
Bilateral findings 14 patients
Total number 22 patients (22 9)
Mean age 56 8 years

highest in the group of radiographic arthrosis The age distribution of the material may account for the rather high radiographic arthrosis frequency no comparable investigations have been found in the literature

The frequency of clinical findings is a little higher than that reported by BOMAN (1947) for his hospital group in which the age distribution was similar

Table 10

Clinical findings in cases with radiographically diagnosed arthrosis

Arthrosis	Clinical findings
Right temporomandibular joint	
	2 clicking
9	1 crepitation and reduced gliding movement
	1 reduced gliding movement
	5 nothing abnormal
Left temporomandibular joint	
	4 clicking
8	4 nothing abnormal
Number of patients	
	6 positive clinical findings
13	7 nothing abnormal

Table 8

Cases with secondary but no primary radiographic findings

	Number of cases			
	Right		Left	
Reduced mobility	15		8	
Possible reduced mobility	2		0	
Retro position	11		12	
Antero position	12		11	
Total number of patients	38	(38.5 %)	28	(29.1 %)
Women	16		15	
Men	22		13	
Patients with dentures	24		19	
Patients without dentures	14		9	

Unilateral findings 23 patients
Bilateral findings 22 patients
Total number 45 patients (46.9 %)
Mean age 54.6 years

indefinite significance (reduced mobility, retro position, antero position) have been grouped as secondary. The interarticular space has been termed 'reduced' when measuring 0.5 mm or less, and the mobility has been termed 'reduced' when the condylar open position was found to be 4 mm, or more, behind the upper part of the articular eminence, provided that a unilateral small opening angle did not indicate insufficient opening of the mouth; in such cases reduced mobility was registered as doubtful.

Changes revealed in the clinical examinations (crepitation, clicking, tenderness, capsular swelling, reduced hinge or gliding movement) have been recorded as positive clinical findings.

Arthrosis was present radiographically in 13 cases or in 13.5 % of the material. The primary radiographic findings that led to this diagnosis are listed in Table 7 together with the accompanying secondary radiographic findings. The number of secondary findings when present alone are shown in Table 8. The frequency of secondary findings was 46.9 % (45 patients).

The results of the *clinical* examination are given in Table 9; 22 patients (22.9 %) had positive clinical findings. None of the results listed in the three tables appeared to be influenced by sex or side but secondary radiographic and positive clinical findings were more frequent among patients with dentures than among those without. This difference is not statistically significant, however, since the number is too small. The mean age was found to be the

Table 12

Comparisons between cases with radiologic diagnosis of arthrosis and total number of cases with positive clinical findings presentin secondary radiographic findings

Secondary radiographic findings	Radiographic arthrosis and/or positive clinical findings
Right temporomandibular joint	
20 reduced mobility	1 arthrosis and pos clin findings 2 arthrosis 5 pos clin findings 12 nothing abnormal
4 possibly reduced mobility	1 arthrosis 1 arthrosis and pos clin findings 2 nothing abnormal
14 retro-position	2 arthrosis and pos clin findings 1 arthrosis 2 pos clin findings 9 nothing abnormal
13 antero-position	1 arthrosis and pos clin findings 12 nothing abnormal
Left temporomandibular joint	
10 reduced mobility	2 arthrosis 8 nothing abnormal
16 retro-position	2 arthrosis and pos clin findings 2 arthrosis 2 pos clin findings 10 nothing abnormal
14 antero-position	? pos clin findings 12 nothing abnormal

Discussion

It has often been stated that lacking correlation between the radiologic and clinical findings must be due to an inefficient roentgen examination, but it could also be due to the fact that comparisons are attempted between cases of incomparable nature

The radiologic diagnosis of arthrosis of the temporomandibular joints is based on clear criteria similar to those used in the diagnosis of arthrosis of other joints

The significance of the clinical findings are usually less definite Clicking, tenderness and reduced mobility may all be caused by intra as well as by extra articular disorders According to KRUSE (1962) clicking may be caused by absence of co ordination between the muscular forces acting on the articular disk and those acting on the condyle as well as by degenerative lesions of the

Table 11

Radiographic findings in cases with positive clinical findings

Positive clinical findings	Radiographic findings
Right temporomandibular joint	
	4 arthrosis
	5 reduced mobility
16	1 possible reduced mobility
	3 retro position
	2 antero-position
	4 nothing abnormal
Left temporomandibular joint	
	1 arthrosis
20	4 retro position
	2 antero position
	11 nothing abnormal
Number of patients	
22	15 primary or secondary radiographic findings
	7 nothing abnormal

to that in the present material. He registered 14.4 % clinical findings among patients without previous symptoms of temporomandibular joint disease, but, including patients with precursive symptoms or findings, he reported that in a total of 32.4 % of the hospital group either subjective or objective changes in the temporomandibular joints had been present at one time or another.

The clinical findings in cases with radiologically diagnosed arthrosis are presented in Table 10, and the radiographic appearances in cases with positive clinical findings in Table 11. The clinical and primary radiographic findings in cases which presented secondary changes in the roentgenograms are registered in Table 12. No satisfactory correlation between the radiologic and clinical findings could be obtained. The same experience was made by NØRGAARD, among others.

It was not possible to determine the value of the secondary radiographic findings, but reduced mobility and retro position seem to be more frequently present in the smaller group of cases with radiographic arthrosis, or with positive clinical findings, than in the larger group with no such findings, while antero position appears to be of no significance. It has not been possible to draw any definite conclusions because of the small number of cases in the material and also because unintentional variations in opening of the mouth and positioning of the head may have occurred.

Table 13

Influence of positioning on the radiographic quality

No	Projection	Quality: Good	Applicable	Inapplicable	Condyle position: Normo-	Retro-	Measurements: D	L	γ
1	Standard	×			×		6 5	18 5	78
2	*frontal 5	×			×		6 5	18	74
3	*frontal 10		×		×		6 5	19	70
4	frontal 15		×		×		7 5	19.5	69
5	Standard	×			×		7	17 5	76
6	occipital 5	×			×		7	18	82
7	*occipital 10	×				Slight	6 5	17 5	87
8	*occipital 15		×			×	7	16 5	93
9	Standard	×			×		7	17 5	74
10	vertical 5	×			×		7	18	77
11	vertical 10			×					
12	vertical 15			×					
13	Standard	×			×		7	18	82
14	basal 5	×			×		6 5	18	77
15	basal 10	×			×		6 5	18 5	72
16	basal 15	×			×		6	18	75
17	Standard	×			×		7 5	17 5	80
18	Flexion 10				×		6 5	18	80
19	Flexion 20	×			×		7	16 5	83
20	Flexion 30		×		×		6 5	16	83
21	Standard	×			×		6 5	18	75
22	Extension 10		×		×		7	17	75
23	Extension 20		×		×		7	18	70
24	Extension 30		×		×		7 5	19	68

* Frontal 5 indicates that the frontal part of the skull was elevated 5

chest) and the same degrees of extension from the first position Roentgenograms in the initial standard position were obtained in between each one of the six series making a total of 24 films These films were grouped as good applicable and inapplicable The projection of the condyle in the fossa was evaluated as representing normo antero and retro position and when possible the depth (D) and length (L) of the articular fossa, as well as the angle (γ) between the tangent to the posterior border of the mandibular ramus and the reference line, were measured

The results are given in Table 13 The smallest influence on film quality was present when the sagittal plane was tilted anteriorly or cranially while

articular disk and surfaces Changes in muscular function, as well as degenerative articular lesions, may lead to reduced mobility of the joint On the basis of these and other considerations, KRUSE suggested that patients with positive clinical findings should be divided into two groups, one including those suffering from degenerative articular disease, arthrosis, and another including those with primarily extraarticular disorders, termed the jaw dysfunction syndrome This syndrome may be present in all age groups but especially between the ages of 20 and 30, and more frequently among women KRUSE believed that a complex of causes may result in temporomandibular joint dysfunction The symptoms would most likely be a result of increased muscular tension, as seen in bruxism, or of changes in the occlusal pattern Mechanical trauma in the temporomandibular joint region could also constitute an etiologic factor

As the clinical differentiation between arthrosis and the dysfunction syndrome is difficult, these two disorders have hitherto been placed in the same group, often termed arthrosis, as suggested by BOMAN (1947) and by FOGED (1949) This may explain why so many of the cases that were clinically diagnosed as arthrosis did not present any radiographic signs of the disease, since degenerative articular lesions, and what the present author has termed primary radiologic findings, are not found primarily in cases belonging to the group of jaw dysfunction This should be kept in mind when the correlation between clinical and radiographic findings is considered unsatisfactory

Influence of positioning on radiographic quality Incorrect positioning of the temporomandibular joints, especially when the sagittal plane of the skull was not parallel to the film plane, was investigated The left temporomandibular joint of a dried skull was examined by the standard technique earlier described, the examination being carried out with the jaw in normal occlusion A radiolucent, 2 mm thick material, was placed in both temporomandibular joints prior to the examination to ensure a suitable interarticular space in the roentgenograms The skull was fixed in a head clamp in order to prevent any unintentional tilting of the sagittal plane, the skull and clamp were then placed upon an adjustable wedge on the skull table, the Frankfort plane forming a 20° anterior and cranially open angle with the transversal axes of the skull table Four series of tilting were carried out, around axis parallel to the longitudinal and transversal axis of the skull table, with raising of the frontal, occipital, vertical and basal parts of the skull, respectively Each series included 5°, 10° and 15° tilting of the sagittal plane Finally, the skull was rotated around an axis through the joint examined, perpendicular to the film plane The rotation included 10°, 20° and 30° flexion ('chin towards the

lateral parts of the articular fossa and the condyle These are the disadvantages of the method when used for diagnosing arthrosis and especially when searching for small changes in condylar position and mobility as an aid in the evaluation of the jaw dysfunction syndrome

It is possible with the aid of arthrography (NORGAARD) to detect degenerative articular lesions not demonstrated by any other means, although most authors have found this method to be technically too complicated to be used outside specialized departments

The technique of choice should be one that permits demonstrating all the parts of the temporomandibular joints with only small distortion and both joints should be simultaneously depicted to allow a comparison of condylar position and mobility It should also ensure sufficient opening of the mouth and should allow the examination to be carried out with the patient in a relaxed upright sitting posture Finally the accuracy of the method should make it possible to obtain identical reproduction of the temporomandibular joints on different occasions Most of these demands seem to be fulfilled by the technique suggested by FLEISCHER & FLEISCHER PETERS (1963) These authors obtained lateral views of both temporomandibular joints by simultaneous multisection tomography the patient sitting in a chair with the head fixed in a head clamp The present author feels that roentgenograms with this technique should be obtained with the teeth in normal occlusion with the jaw in the so called rest position as well as after full opening of the mouth The last position should be stabilized by means of a wedge inserted between the teeth Only an experimental study will however indicate whether these theoretical considerations are of practical value

Acknowledgement

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SUMMARY

The temporomandibular joints of 96 patients without previous symptoms of disease were examined clinically and radiographically The normal values of the joint parameters and condylar movements were studied and the correlation between the clinical and radiologic findings evaluated The influence of positioning upon the radiographic quality was investigated experimentally

early tilting in the opposite directions resulted in reduction of the radiographic quality The posterior tilting of the sagittal plane also resulted in a projection of the condyle backwards in the articular fossa, giving a false impression of retro position

The investigation has indirectly shown that a reduction of the usual 25° angling of the central ray from above/downwards would allow greater variations in positioning without reduction of the radiographic quality Additional angling a little less than 10° from behind/forwards would, for the same reasons, be preferable The investigation thus provides evidence in support of the angling suggested by LINDBLOM 15° from above/downwards and 15° from behind/forwards Other authors, such as NORGAARD, have obtained the last mentioned angling by tilting the sagittal plane of the skull and directing the nose of the patient 10° to 15° towards the film plane A higher degree of accuracy is of course possible by the first mentioned method but because of the 15° angling of the central ray from behind forwards, it is necessary to turn the Bucky diaphragm of the skull table 15°

The films obtained upon rotation of the skull lost quality rapidly during extension, while 20° flexion could be carried out without disadvantage This should be remembered when the positioning is considered

The measurement values of D, L, and y, in films of good radiographic quality varied only slightly during tilting and rotation The results are presented in Table 13 For the roentgenograms, the error of measurement was calculated from the six examinations in the standard position It is assumed that with the technique used differences in projection only slightly influenced the values The error in measurement of the depth of the articular fossa (D) amounts to 0 38 mm, the corresponding value for the length of the fossa (L) being 0 35 mm, and that for the condylar angle (y) 3 08°

Conclusion

It would appear that the Schuller projection will generally produce suitable views of the region of the temporomandibular joint, in the diagnosis of fractures, luxations and congenital or acquired deformities its value cannot be doubted It has however been confirmed by the present investigation that undesirable variations, caused by insufficient opening of the mouth or by alterations in positioning, may sometimes give a false impression of reduced mobility or of retro position It must also be admitted that the dynamic forces acting on the temporomandibular joints when the patient is examined in the prone position are not physiologic MAROLT (1957) has shown in an experimental study that the Schuller projection depicts only the extreme

lateral parts of the articular fossa and the condyle These are the disadvantages of the method when used for diagnosing arthrosis and especially when searching for small changes in condylar position and mobility as an aid in the evaluation of the jaw dysfunction syndrome

It is possible with the aid of arthrography (NORGAARD) to detect degenerative articular lesions not demonstrated by any other means although most authors have found this method to be technically too complicated to be used outside specialized departments

The technique of choice should be one that permits demonstrating all the parts of the temporomandibular joints with only small distortion and both joints should be simultaneously depicted to allow a comparison of condylar position and mobility It should also ensure sufficient opening of the mouth and should allow the examination to be carried out with the patient in a relaxed upright sitting posture Finally the accuracy of the method should make it possible to obtain identical reproduction of the temporomandibular joints on different occasions Most of these demands seem to be fulfilled by the technique suggested by FLEISCHER & FLEISCHER PETERS (1963) These authors obtained lateral views of both temporomandibular joints by simultaneous multisection tomography the patient sitting in a chair with the head fixed in a head clamp The present author feels that roentgenograms with this technique should be obtained with the teeth in normal occlusion with the jaw in the so-called rest position as well as after full opening of the mouth The last position should be stabilized by means of a wedge inserted between the teeth Only an experimental study will however indicate whether these theoretical considerations are of practical value

Acknowledgement

The clinical investigation was kindly carried out by Dr Peter Rasmussen Department of Neurosurgery Kommunehospitalet Aarhus Denmark

SUMMARY

The temporomandibular joints of 96 patients without previous symptoms of disease were examined clinically and radiographically The normal values of the joint parameters and condylar movements were studied and the correlation between the clinical and radiologic findings evaluated The influence of positioning upon the radiographic quality was investigated experimentally

ZUSAMMENFASSUNG

Die Temporo Mandibulargelenke von 96 symptomlosen Patienten wurden klinisch und rontgenologisch untersucht Die Normalwerte für den Gelenkparameter und die condylare Beweglichkeit wurden bestimmt und die Korrelation zwischen den klinischen und rontgenologischen Befunden ermittelt Der einfluss der Einstellung auf die Güte des Rontgenbildes wurde *experimentell uberpruft*

RÉSUMÉ

L auteur a *examiné cliniquement et radiologiquement les articulations temporo maxil* laires de 96 sujets n ayant pas présenté de symptomes d affection de cette articulation Il a étudié les valeurs normales des paramètres articulaires et des mouvements des condyles et a évalué la corrélation entre les signes cliniques et radiologiques Il a étudié expérimenta lement l'influence de la position du sujet sur la qualité des radiographies

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FROM THE ROENTGENDIAGNOSTIC CLINIC (ACTING DIRECTOR B LILIEQUIST)
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ROENTGENOLOGIC EXAMINATION OF THE ACETABULAR PART OF OS COXAE

by

BENGT LILIEQUIST

Several projections have been described for the roentgenologic examination of the hip joint A frontal view with inward rotation of the shaft of the femur is usually used for the examination of both the hip joint and the pelvic bone in combination with a projection in which the femur is abducted and rotated outwards Fractures of the femoral neck will include a lateral view with a horizontal beam direction BILLING has described more exact projections of the femoral head and neck for special purposes Common to all these views is the fact that they permit examination only of the shape and relative position of the proximal end of the femur The ordinary principle for the investigation of joints and surrounding bones comprises two projections at right angle to each other and is followed in the examination of the proximal end of the femur but not in that of the acetabular region of the hip bone

WALLER described a special projection for the examination of the posterior aspect of the acetabulum in order to demonstrate fractures of its posterior

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Fig. 1. Lateral view showing the normal appearance of the acetabular part of the hip bone.





Fig. 2. A.p. view (left) shows considerable destruction of the hip bone including acetabulum. The lateral view (right) shows that the destruction is mainly located posteriorly in the acetabular part of the hip bone.

border, so called dashboard fractures, but this projection is less suited for the rest of the acetabulum. A similar projection has recently been described by LAMY & LEVI-VALENSIN.

The need of a simple method for examining the acetabular part of the hip bone in two projections frequently exists, one of them preferably a frontal and the other a lateral view. The relationships of the ilium and its synostoses with the ischium and pubis should be demonstrated.

The hip bone is formed of three bones, the ilium, ischium and pubis. These are separated until the age of 17 years when they merge into a single bone. The hip bone is directed ventrodorsally, which will not be evident from the commonly used a.p. views. Pathologic changes in the bone surrounding the hip joint therefore necessitate an additional projection.

A suitable projection of the acetabular part of os coxae can be realized with the patient lying on the side with the pelvis tilted slightly forwards so that the hip joint to be examined is nearest to the film and will be projected midway between the sacrum and the other hip joint: the bony points are controlled by palpation. The central beam is directed through a point midway between the sacrum and the greater trochanter of the uppermost hip joint, at right angles to the roentgen film. The exposure data are the same as for a lateral view of the sacrum. As the central beam is not angulated, one possible source



Fig 3 Arthrodesis of the left h p-joint with a nail A p view in (a) A lateral view of the femoral neck (b) suggests that the tip of the nail s apparently in the ileum but a lateral v ew of the acetabulum (c) shows that the na l actually lies outs de the ileum

of erro in performing the examination is eliminated Distortion of the ana tomic il details that are not parallel to the plane of the film will also be avoided if use is made of an orthograde central projection

The normal anatomy is depicted in Fig 1 The large extension of the acetabular part of the hip bone in a ventrodorsal direction is evident and the anterior and posterior aspects of the iliac synostoses are outlined

Pathologic changes in the acetabular part of the hip bone are best studied in a lateral view as in the case of a large destructive lesion it cannot be deter mined from an a p view whether its largest extension is in the anterior or posterior part of the acetabulum and this information is necessary for deciding how a probe excision should be made The roentgenograms in Fig 2 illustrate these points it is revealed in the lateral view that the larger area of destruction is located posteriorly

Arthrodesis of the hip joint is performed by introducing a nail through the femur into the ileum Ordinary projections of the hip joint will fail to demonstrate the exact position of the nail The conventional a p and lateral views of the femoral neck may suggest that the extremity of the nail lies in the ileum when in fact it may lie well outside A lateral projection of the acetabular part of the hip bone must be obtained to indicate the position of the nail in relation to the hip bone

SUMMARY

An easy procedure for obtaining a lateral roentgenogram of the acetabular part of the hip bone is described The normal anatomy is discussed and the value of the projection is illustrated in two cases

ZUSAMMENFASSUNG

Eine einfache Methode der seitlichen Rontgenaufnahme der Hüfte die leicht ausfuhrbar ist wird angegeben Die normale Anatomie wird besprochen und der Wert der Methode wird durch zwei Fälle illustriert

RÉSUMÉ

Description d une incidence radiographique de profil de la partie acétabulaire de l os iliaque, d exécution facile L auteur étudie l anatomie normale de cette incidence et montre son intérêt dans deux cas

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WALLER Å Dorsal acetabular fractures of the hip (Dash board fractures) Acta chir scand Suppl 205 (1935)

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ARTERIA MAGNA ET DOLICHO OF LERICHE

by

T W STAPLE M J FRIEDENBERG M S ANDERSON and H R BUTCHER Jr

During the years 1942—1945 LERICHE described the clinical arteriographic and operative findings in two patients with extraordinary elongation and dilatation of the pelvic and common femoral arteries which before operation were mistaken for aneurysms In one patient, the accompanying veins were similarly involved LERICHE termed this disease arteria (vena) magna et dolicho and did not suggest that arteriosclerosis was the cause of the condition These vessels were however not microscopically examined ACKERMAN & BUTCHER (1964) in their text on surgical pathology, mentioned this condition, but there has been no further reference to it in the English literature In order to determine whether these abnormalities represent a specific type of vascular disease the femoral or aorto-ilio femoral arteriograms of 670 patients were reviewed (FRIEDENBERG & CARLSON 1965) The present communication is a report on the clinical roentgenographic and pathologic findings in 9 patients in whom the arteries in the pelvis and/or lower extremities were similar to those described by LERICHE

Submitted for publication 24 March 1964

SUMMARY

An easy procedure for obtaining a lateral roentgenogram of the acetabular part of the hip bone is described. The normal anatomy is discussed and the value of the projection is illustrated in two cases.

ZUSAMMENFASSUNG

Eine einfache Methode der seitlichen Röntgenaufnahme der Hüfte, die leicht ausführbar ist, wird angegeben. Die normale Anatomie wird besprochen und der Wert der Methode wird durch zwei Fälle illustriert.

RÉSUMÉ

Description d'une incidence radiographique de profil de la partie acétabulaire de l'os iliaque d'exécution facile. L'auteur étudie l'anatomie normale de cette incidence et montre son intérêt dans deux cas.

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Table 1 (*cont*)

Pulses								Appearance of extremity
Femoral		Popliteal		Posterior tibial		Dorsalis pedis		
R	L	R	L	R	L	R	L	
3+	3+	3+	3+	0	0	1+	2+	Blue toes LLE slightly tender & cool L calf
Good	Good	Good	0	Good	0	Good	0	Normal
1+ with bruit	2+	0	1+	0	1+	0	1+	Normal
2+	2+	2+	4+	2+	2+	2+	2+	Normal
4+	4+	4+	4+	4+	4+	4+	4+	Normal
3+	3+	3+	3+	2+	0	0	0	Cool legs below knees
2+	2+	3+	2+	1+	0	1+	0	Cyanosis L toes
4+	4+	4+	4+	2+	2+	2+	2+	Normal
3+ with bruit	2+ with bruit	4+ with bruit	2+	0	2+	2+	2+	Normal

The blood pressure of the four patients with hypertension was 160—180 systolic and 100—120 diastolic All patients had at least one pulsatile mass in the abdomen pelvis or lower extremity and several had more than one The arterial pulses peripheral to the pulsatile masses were either diminished or absent

The blood counts and urine analyses of all patients were normal Serological tests for syphilis were negative in seven patients and were not done in two Circulation times in four patients were 15 21 23 and 28 seconds In one patient the circulation time decreased from 28 to 22 seconds following digitalization Venous pressures in these four patients were 45 55 100 45 mm saline

Table 1

Clinical data in a material of 9 cases (Caucasian men) in ages between 50 and 76 years

	History	Physical examination (R = right L = left B = bilateral)		
	Intermittent claudication	Constant pain in extremity	Hyper tension	Pulsatile mass
Case 1 65WM	LLE 2—3 months	LLE 24 hours	0	L popliteal
Case 2 64WM	LLE 6 years	0	+	R popliteal L iliac L common femoral
Case 3 56WM	B Lower extremities 10 years	Abdomen (LLQ) 1 month	+	Abdomen (LLQ)
Case 4 50WM	B lower extremities several years	0	+	Abdomen
Case 5 74WM	0	0	0	Abdomen (RLQ) B femoral
Case 6 76WM	0	L calf 2 1/2 months	0	Mid abdomen B inguinal
Case 7 74WM	0	L foot & ankle 1 week	+	L popliteal with systolic murmur
Case 8 74WM	0	0	0	Abdomen (RLQ) R superficial femoral
Case 9 61WM	R foot 5 years	R foot 6 weeks	0	R superficial femoral

Clinical findings

All 9 patients were Caucasian men, 50 to 76 years of age (see Table 1) Four patients had hypertension There were no members of the patients' families known to have similar vascular disease The chief complaint in six patients was pain in one or both lower extremities Five patients had unilateral or bilateral intermittent claudication of two months to ten years duration Four patients had constant pain in a lower extremity of twenty four hours to two and one half months duration, in three of them, this pain was sudden in onset One patient had left lower quadrant pain for one month Pulsatile masses were felt in the abdomen by three patients and behind the knee by two

Table 2 *(cont.)*

Aneurysm	Lumen margin	Vessel course	Symmetry of involvement
None	Markedly irregular	Tortuous	Unknown
Abdominal aorta R internal iliac B common femoral	Markedly irregular	Tortuous	Bilateral
None	Markedly irregular	Tortuous	Unknown
Abdominal aorta L popliteal	Markedly irregular	Tortuous	Unknown
None	Markedly irregular	Normal	Bilateral
R popliteal B common femoral B common iliac	Markedly irregular	Tortuous	Bilateral
Abdominal aorta B common iliac	Markedly irregular	Tortuous	Bilateral
B common femoral	Markedly irregular	Tortuous	Bilateral
Abdominal aorta L common femoral	Markedly irregular	Tortuous	Bilateral

Roentgen findings

The arteries examined angiographically in all 9 patients had abnormally wide lumina with irregular margins. The arteries were quite tortuous in eight of the individuals. One superficial femoral artery was occluded completely in three patients. The remaining six had either no occlusions or occlusions only of the popliteal artery branches. Aneurysms were demonstrated in six patients (Figs 1 to 3). The vascular disease was bilaterally symmetrical in six patients

Table 2

Roentgen findings in the case material (R = right, L = left B = bilateral)

Patient	Peripheral soft tissue calcification	Sites of occlusion	Speed of circulation	Vessel caliber
Case 1	3+	None Arteries examined only to popliteal	Slow	Markedly widened
Case 2	1+	R superficial femoral	Unknown	Normal
Case 3	2+	Posterior tibial	Slow	Markedly widened
Case 4	None	None	Normal	Wide
Case 5	None	Trifurcation arteries	Slow	Markedly widened
Case 6	Unknown	L superficial femoral	Slow	Wide
Case 7	None	R superficial femoral *Arteries examined only to* popliteal	Unknown	Wide
Case 8	Unknown	Poor outflow both vessels	Unknown	Wide
Case 9	None	None	Slow	Wide

respectively Eight patients had normal fasting blood sugar levels, and this test *was not done in the ninth* Blood cholesterol and protein concentrations were not determined

Three patients had electrocardiographic changes of old myocardial infarction, two patients had left bundle branch block with ventricular premature contractions, and two patients had arrhythmias (1 atrial fibrillation and 1 atrial flutter or premature atrial contractions)



Fig 2 Case 2 Composite print of 3 roentgenograms obtained following pressure injection of contrast material through a catheter in the right common iliac artery Aneurysms of the abdominal aorta right internal iliac and both common femoral arteries all the pelvic arteries are dilated and elongated

recent thrombi The vessels were abnormally large as illustrated in Figs 5 to 7 Thickness of the arterial walls in these patients ranged from 0 3 to 1 0 cm Microscopically the changes visible in the walls of the arteries were essentially those of advanced arteriosclerosis Platelet and fibrin thrombi were often found to be adherent to the surfaces of atheromatous material The atheromas were composed of an amorphous substance, cholesterol clefts and lipid laden macrophages At the margins and bases of the atheromas, fibrosis and numerous calcareous deposits extended into the media No bone was present The media was thinned irregularly beneath these deposits The elastic fibers were fragmented discontinuous and frayed Complete loss of the media and muscular coats occurred at several points in one circumferential plane of an arterial wall At these points only the adventitia remained to sustain the integrity of the arterial wall Lymphocytes (frequently perivascular) hemosiderin filled histiocytes



Fig 1 Case 4 Manual injection of contrast medium through a needle in the left common femoral artery Aneurysms of the abdominal aorta and left popliteal artery are present the left iliac arteries are dilated and elongated and the superficial femoral artery is dilated

the opposite extremity was not examined in the remaining three A striking finding was the usually slow arterial flow in five patients In these patients, 15 to 20 seconds, or more elapsed between the end of the injection of contrast material in the common femoral artery and its arrival in the branches of the popliteal artery The speed of arterial flow was normal in one patient, and was not recorded in three Calcification of the arterial walls was seen in three of the seven patients having roentgenograms before arteriography Periosteal reaction of the tibia was present in two patients, one of whom had chronic venous insufficiency Phlebography was not performed in anyone of the patients

Pathologic findings

Specimens were available for pathologic examination in six patients Grossly, the arteries were dilated and partly occluded by artheromatous material and



Fig 2 Case 2 Composite print of 3 roentgenograms obtained following pressure injection of contrast material through a catheter in the right common iliac artery Aneurysms of the abdominal aorta right internal iliac and both common femoral arteries all the pelvic arteries are dilated and elongated

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Fig 3 Case 6 Bilateral simultaneous femoral arteriograms with reflux aortogram Aneurysms of the abdominal aorta common iliac common femoral and right popliteal arteries with marked dilatation and elongation of all arteries examined The popliteal artery aneurysm is almost completely filled with blood clot

and focal fibrosis were present in the adventitia Partial thrombotic occlusions along the arteries were frequent

The histological features were identical to the usual form of arteriosclerosis in which atheroma serves as a foundation upon which thrombosis occurs The walls of the arteries could not be distinguished from those of resected arteriosclerotic aneurysms None of the surgical specimens contained large veins

Since dilatation and tortuosity of the vessels were such prominent features in these patients, the structure and composition of the arterial walls were evaluated to determine if there was any specific defect of muscle or elastic tissue No such abnormality was found either by conventional or special staining techniques



Fig 4 a) Case 1 b) and c) Case 3 d) e) and f) Case 5 Femoral arteriograms show abnormally dilated arteries with markedly irregular luminal margins The arterial occlusions are limited to the trifurcation vessels All patients had unusually low blood flow

Discussion

The 9 patients included in this report demonstrated a unique combination of angiographic findings This consisted of unusually slow flow of contrast material through abnormally dilated and elongated arteries with markedly *irregular luminal margins There was bilaterally symmetrical involvement in* those patients in whom both extremities were examined Although there was a high incidence of aneurysms more often angiography demonstrated dilated and tortuous arteries which simulated aneurysms clinically

In 8 of 9 patients angiography did not demonstrate the usual *form of arterio* sclerotic vascular disease The vessels in these patients were widely patent except for those areas of complete *occlusion This* is in contradistinction to the usual



Fig 3 Case 6 Bilateral simultaneous femoral arteriograms with reflux aortogram Aneurysms of the abdominal aorta common iliac common femoral and right popliteal arteries with marked dilatation and elongation of all arteries examined *The popliteal artery aneurysm is almost completely filled with blood clot*

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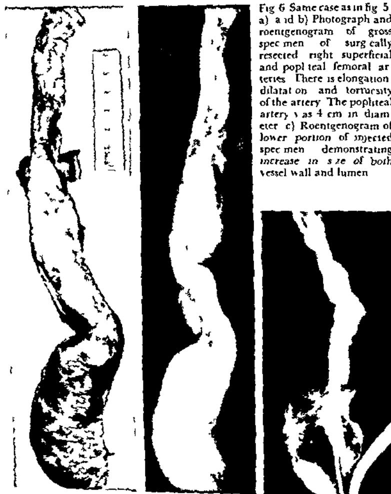


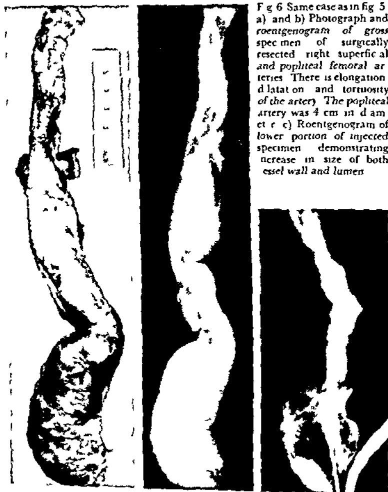
Fig 6 Same case as in fig 5 a) a ıd b) Photograph and roentgenogram of gross spec men of surg cally resected right superficial and popl teal femoral ar teries There is elongation dilatat on and tortuosity of the artery The popliteal artery \ as 4 cm in diam eter c) Roentgenogram of lower portion of injected spec men demonstrating *increase in s ze of both* vessel wall and lumen



Fig. 5. Case 9. *Aorto-ilio-femoral* arteriogram with manual injection of contrast material through a needle in the right common femoral artery. There is marked dilatation of all major arteries and tortuosity of the right distal superficial femoral and entire popliteal artery. Left view is a composite of two roentgenograms.

form of arteriosclerosis which is characterized by multiple areas of varying degrees of partial or complete segmental occlusion. Also, the sites of occlusion *in these patients tended to be located distally, rather than distributed among* proximal and distal arteries. The appearance of the complete occlusions in the smaller, more peripheral arteries suggested embolic disease.

The arterial disease present in these patients appears to be a variant of the usual form of arteriosclerosis. The slow blood flow probably is related to the increased cross sectional area of the arterial lumina. Arteriography is prerequisite for a diagnosis of arteria magna et dolicho of Leriche, and permits the identification of the aneurysms frequently associated with this abnormality. During arteriography delayed timing of film exposure is required to ensure adequate examination of distal arteries.



F g 6 Same case as in fig 5 a) and b) Photograph and *roentgenogram of gross* spec men of surgically resected right superfic al *and popliteal femoral ar* teries There is elongation d latat on and tortuosity *of the artery The popliteal* artery was 4 cm in d am et r c) Roentgenogram of lower *portion of injected* specimen demonstrating ncrease in size of both *essel wall and lumen*

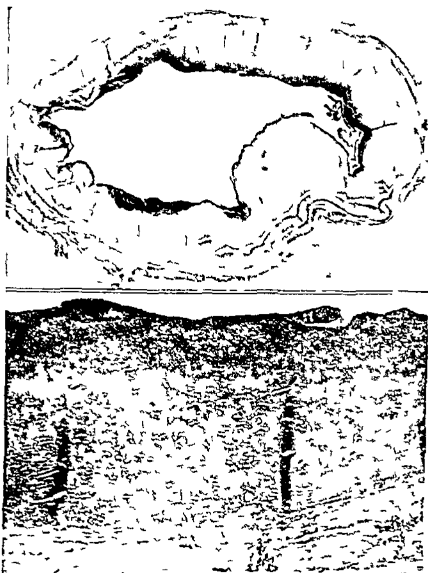


Fig 7 Same case as in figs 5 and 6 *Upper* Histologic cross section of artery showing atheromatous material replacing the intima and focally destroying the media An irregular large lumen remains H & E × 8 *Lower* Histologic section of wall of vessel Destruction of media by atheroma containing many cholesterol clefts in this area only the adventitia remains to maintain the integrity of the vessel wall H & E × 50

SUMMARY

The clinical roentgenographic and pathologic findings in arteria magna et dolicho of Leriche a unique form of arteriosclerosis are described The roentgen findings are characterized by unusually slow flow of contrast material trough dilated and tortuous arteries with markedly irregular margins The microscopic changes are indistinguishable from the usual form of arteriosclerosis Arteriography is required to make the diagnosis and to identify the frequently associated aneurysms

ZUSAMMENFASSUNG

Die Befunde bei klinischen rontgenographischen und pathologischen Untersuchungen in Fallen von Arteria magna und Dolicho nach Leriche einer einzigartigen Form der Arteriensklerose werden beschrieben Ein ungewohnlich langsamer Fluss des Kontrastmaterials durch erweiterte und gewundene Arterien mit deutlich unregelmassigen luminalen Randern wurde als charakteristisch fur die Rontgenbefunde bezeichnet Die mikroskopischen Veranderungen sind von der gewohnlichen Form der Arteriosklerose nicht zu unterscheiden Um die Diagnose zu stellen und die haufig assoziierten Aneurysmen zu identifizieren ist Arteriographie erforderlich

RÉSUMÉ

Description des signes cliniques radiologiques et anatomo-pathologiques de la mégadolicho-artère de Leriche qui est une forme bien individualisée d artériosclérose Les signes radiologiques se caractérisent par l écoulement inhabitu llement lent du moyen de contraste dans des artères dilatées et tortueuses dont la lumière a des bords tres irréguliers Les lésions microscopiques sont identiques à celles de la forme habituelle d artériosclerose L artériographie est indispensable pour diagnostiquer les anévrismes qui sont fréquemment associés a cette affection

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ANGIOGRAPHY IN TUMOURS OF THE STOMACH

by

ERIK BOIJSEN, SIDNEY WALLACE and IRA F. KANTER

Angiography is well established as an effective method of diagnosis. It has become apparent that the selective injection of contrast media still further improves its capabilities. The value of the selective approach has been well documented in nephro-angiography. Selective celiac and superior mesenteric angiography have given some hope for similar results in the abdominal organs supplied by these vessels. The intention with this investigation was to evaluate selective celiac and superior mesenteric angiography as a complementary method in the diagnosis of gastric neoplasms.

Anatomy. The vascular supply of the stomach has recently been described in detail (MICHELS 1955). It has been shown that this supply may be demonstrated by celiac angiography (BIERMAN et coll. 1951, MORINO et coll. 1958, ÖDMAN 1958, PIRKER 1961, BOIJSEN & OLIN 1961).

The stomach is nourished by branches of the celiac artery, i. e. the hepatic, splenic, and left gastric arteries and their branches and terminal divisions. The gastric vasculature may be divided into a primary and secondary supply (MICHELS). The primary supply includes the left and right gastric vessels,

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Fig 1 Woman aged 54 with an ulcerating adenocarcinoma of the antrum a) Superior mesenteric angiogram Common hepatic and gastroduodenal arteries arising from the superior mesenteric artery Tumour supply from the right gastric and right gastroepiploic arteries infiltration of the latter indicates extension through the gastric wall to the omentum (→) b) c) Combined celiac and superior mesenteric angiogram Accumulation of medium within the tumour (↔) corresponds to limits of lesion as evident in barium study Better delineation accomplished by inflating the stomach



a



b



c

forming the superior arcade adjacent to the lesser curvature the right and left gastroepiploic arteries making up the inferior arcade along the greater curvature the short gastric arteries arising from the splenic artery and the gastroduodenal a branch of the hepatic artery The secondary supply consists of the anterior superior pancreaticoduodenal, supraduodenal posterior superior pancreaticoduodenal (retroduodenal) transverse pancreatic dorsal pancreatic and inferior phrenic arteries

Technique Selective arterial catheterization was performed by the Seldinger technique from either the femoral or axillary arteries when combined celiac and superior mesenteric artery injections were made one catheter was intro-



a

Fig. 2. Man aged 61. Polypoid carcinoma. a) Irregular mass involving greater curvature. b), c) Combined celiac and mesenteric angiography. Gastric origin of tumour verified by primary arterial supply from the right gastroepiploic artery which is enlarged in diameter. Aneurysm (→) and infiltration (↦) of right gastroepiploic artery, luminal irregularities and accumulation of medium in the tumour.



b



c

duced into each femoral artery. Demonstration of the celiac axis and its branches usually delineated the supply of the stomach. It was also necessary in the presence of anomalous vessels to inject the superior mesenteric artery to fill the gastroduodenal and right gastroepiploic arteries. It was found in these instances that the injection of the celiac and superior mesenteric arteries individually minimized overlapping of the smaller peripheral vessels, which are most important in the diagnosis of gastric diseases.

The left axillary approach has recently been employed with greater frequency. This *retrograde technique more readily permitted selective catheterization* of branches of the celiac artery (BOIJSEN, to be published). The hepatic, gastroduodenal, and the splenic arteries have been injected separately. The left gastric artery could not be selectively catheterized with any consistency



Fig 3 Man aged 68 a) Squamous cell carcinoma at esophago-gastric junction. b) c) Celiac angiography Hypervascular tumour supply vascular luminal irregularities and accumulation of medium in the tumour (→)

The red radiopaque Ödman Ledin polythene catheter shaped as described by ÖDMAN, with no side holes was utilized to allow the delivery of an adequate amount of contrast medium without totally occluding the branches of the celiac artery and 30 ml of Urografin 60 % were injected in 3 to 4 seconds at a pressure of 3 kg/cm² (Gidlund injector) Combined celiac and superior mesenteric injections were made by injecting a total of 50 ml Urografin 76 % via a Y adapter under 4 kg cm² pressure Serial roentgenograms to include the complete portal venous phase were exposed over a 25 second period

The patient was sometimes given aerated water to distend the stomach Proper positioning of the patient important in delineating the vascular distribution to the lesion was determined from the upper gastrointestinal study

The antral pyloric and lesser curvature lesions were best depicted by varying degrees of rotation in the left posterior oblique position, because the superior gastric arcade was seen in profile A higher greater curvature or posterior lesion was best demonstrated in the right posterior oblique position An a p projection was often also useful in determining the vascular anatomical distribution

Results

The material in the present study consisted of 31 patients with gastric neoplasms originally diagnosed by barium meal examinations Selective



Fig 4 Man aged 75 with subtotal gastrectomy performed 18 years previously for peptic ulcer Polypoid adenocarcinoma of fornix with liver metastases b) c) Celiac angiography Hypervascular tumour (→) with tumour vessels originating from short gastric arteries arterial and capillary changes of liver metastases

celiac artery injection was performed in all the patients with the addition of superior mesenteric arteriography in six The diagnosis was confirmed histologically in all the patients except one in whom the changes were so extensive that exploration was contraindicated

The gastric lesions reviewed included both benign and malignant tumours Histologically the great majority (24) were adenocarcinomas, while squamous cell carcinoma (3), leiomyoma (1), neurinoma (1), lymphosarcoma (1), and reticulum cell sarcoma (1) were also represented The adenocarcinomas were found in all parts of the stomach and included examples of scirrhous, polypoid, and ulcerating tumours in approximately equal numbers The squamous cell carcinomas were both scirrhous and polypoid and were located at the esophagogastric junction The sarcomas were fairly extensive and infiltrated the body and the antrum while the benign tumours were intramural and involved the body of the stomach

Changes in the gastric vascular supply Whenever possible the diameters of the major vessels supplying the stomach were arbitrarily measured at a point one centimeter distal to their origin These vessels, except for the right gastric artery, were identified and measured in at least 75 % of the patients The width of the common hepatic artery ranged from 5 to 12 mm (mean 8 mm), the splenic 5 to 10 mm (mean 8 mm), the left gastric 2 to 6 mm (4 mm), the



a

Fig 5 Woman aged 60 with an ulcerating ad nocarcinoma a) Celiac angiography Hy pervascularity with luminal irregularities (→) and accumulation of medium in the tumour originating from the right gastroepiploic ar tery Inflammatory hypervascularity of greater curvature (↔) b) c) Celiac angiography with stomach inflated Tumour vessels arise also from the right and left gastric arteries



b



c

gastroduodenal 3 to 7 mm (4 5 mm) and the right gastroepiploic artery 3 to 7 mm (4 5 mm) The right gastric artery could be outlined definitely in 9 patients and ranged from 1 to 3 mm (mean 2 mm)

There was considerable variation in the origin of these vessels but their distribution was fairly consistent The common hepatic artery including the gastroduodenal and its branches arose from the superior mesenteric in one



Fig. 6. Woman aged 70. Scirrhous adenocarcinoma. a) Upper gastrointestinal study. b) Celiac angiography. Tumour vessels with luminal irregularities in the thickened wall.

patient (Fig. 1). The gastroduodenal artery in another patient arose from a branch of the celiac artery which continued as the supply to the quadrate lobe of the liver.

Extensive and marked displacement of the major vessels from their normal course by the primary gastric lesion occurred in 7 patients. Infiltration of the primary vessels by the gastric neoplasm was recorded in 2 patients (Figs 1, 2). These two characteristics were of greater importance in determining the extension of the tumour outside the stomach.

The vascular pattern was evaluated according to the criteria established from angiography of tumours in general (BIELING & LINDGREN 1911, WICKBOM 1953, LAGERGREN et coll. 1960, McALISTER et coll. 1962). These included an increase in the number of vessels, neovascularization or infiltration of vessels producing luminal irregularities, irregular or homogeneous accumulation of contrast medium in the lesion, and a deviation in the course of normal vessels. Arteriovenous shunts frequently observed in highly vascular tumours were extremely rare in gastric neoplasms. These criteria were applied in the evaluation of the primary lesion and its extension. The angiographic interpretations were compared with the appearance of the lesion in the upper gastrointestinal tract study, and in the operative and autopsy findings.

Hypervascularity (Figs 3 and 5), luminal irregularities (Figs 5 and 6), and accumulation of contrast medium (Figs 2 and 3) were demonstrated in all but one of the malignant lesions; distortion or deviation of the normal vessels was present to a lesser degree.

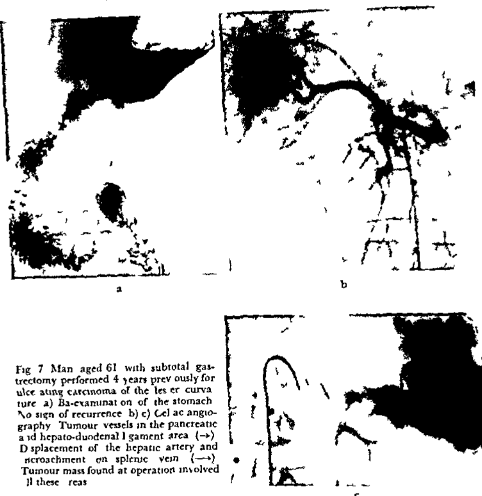
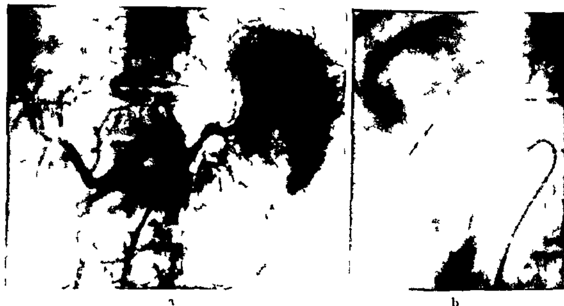


Fig 7 Man aged 61 with subtotal gastrectomy performed 4 years prev ously for ulce ating carcinoma of the les er curvature a) Ba-examinat on of the stomach No sign of recurrence b) c) Cel ac angiography Tumour vessels in the pancreatic a d hepato-duodenal l gament area (→) D splacement of the hepatic artery and ncroachment on splenic vein (⟶) Tumour mass found at operation involved ll these reas

An attempt was made to diagnose extension both contiguous with and distal to the primary tumour (Table) and the operative reports were scrutinized for histologic evidence of such extension All four patients with liver metastases at laparotomy were diagnosed by angiography (Fig 4) One other patient with obvious massive involvement of the liver was not explored Five patients had extension to the hilum of the liver in the hepatoduodenal ligament, four of these being diagnosed by angiography (Fig 7) In addition one patient had narrowing of the portal vein and exploration was not considered advisable (Fig 8) Encroachmen upon the splenic vein was observed at angiography in both patients with extension to the splenic hilum (Figs 7 and 9) The



a b

Fig 8 Man aged 74 with an ulcerating adenocarcinoma of cardia and body celiac angiography The tumour is supplied by the left and right gastric and left and right gastroepiploic arteries Extension to hepatoduodenal ligament demonstrated by irregular vessels and narrowing of portal vein (→)

patient with lymphosarcoma had involvement of the duodenum, which was depicted angiographically Less successful was the ability to diagnose extension to the pancreas (Fig 7), omentum, transverse mesocolon, and various lymph nodes Infiltration of the anterior abdominal wall, diaphragm, subserous fatty tissue, and the retroperitoneal area escaped detection

Table

Local and distant extension of the primary gastric tumours found at angiography and during operation

Extension	Angiography	Operation
Liver	5*	4
Portal vein and hepato duodenal ligament	5*	3
Spleen	2	2
Pancreas	2	6
Omentum	2	8
Transverse mesocolon	1	7
Lymph nodes	1	10
Other	1	6

*One patient not explored because of obvious extensive involvement



a

Fig 9 Man aged 69 Polypoid adenocarcinoma a) Upper gastrointestinal study b) c) Celiac angiography Displacement of branches of left gastric and short gastric arteries tumour vessels and accumulation of medium evident Extension demonstrated by compression of splenic vein (→)



b



c

There were only two benign tumours represented in the present study, one neurinoma and one leiomyoma Both these tumours exhibited most of the vascular changes within the primary tumour bed, which have been described for malignant lesions (Figs 10 and 11)

Discussion and Conclusions

In view of the increased vasculature demonstrated in gastric lesions the major vessels were evaluated for a concomitant increase in their diameters The range and mean measurements of the diameter of the primary arteries fall well within the wide range of the normal reported by ÖDMAN at angio-



a



b

Fig 10 Woman aged 51 Neurinoma a) Upper gastrointestinal study Two masses involving the greater and lesser curvatures b) Combined celiac and superior mesenteric angiography The gastric origin of the masses revealed by the gastric artery supply to the lesions Tumour vessels arise from the left gastric (→) and left (↦) and right (↦→) gastroepiploic arteries The left gastroepiploic artery is displaced over the tumour The left colic artery is displaced but does not supply the tumour

graphy In only one patient was it possible to demonstrate a definitely enlarged vessel supplying the tumour area (Fig 2) The narrow caliber of the right gastric artery was probably the causative factor in the frequent failure of its demonstration This was compared to MICHELS study in which a small gastric artery with an average diameter of 2 mm was identified in all of the 200 cadavers dissected

Careful attention was given to the origin and course of the major vessels, for this was of importance in the differentiation of intrinsic from extrinsic lesions (Figs 2, 10 and 11) The vascular supply of a gastric lesion arose from a primary gastric vessel Actual displacement of these vessels was observed only in the presence of very large tumours

The angiographic diagnosis of tumours of the stomach depended upon the adequate demonstration of the vasculature of the tumor bed itself Previous authors had found that malignant tumours of the stomach were poorly vascularized (BILLING & LINDGREN 1944) and that the angiographic diagnosis depended on secondary changes (ÖDMAN 1958) More recently, evidence has accumulated that there is an increase in the number of vessels in the tumour area, which are finer in caliber than normal Certain areas, particularly the floor of an ulcer crater, are considered relatively avascular Operative and microangiography have demonstrated in great detail the normal and



Fig 11 Woman aged 53 Leiomyoma a) Upper gastrointestinal study Partly calcified mass involving the posterior wall of the body b) Celiac angiography Gastric origin of the lesion demonstrated by the left gastric artery supply (→) the branches of which are displaced Tumour vessels evident but the smooth outline suggests a benign mural lesion

abnormal vascular patterns of the stomach (KEY 1950 BARCLAY 1951, MARGULIS & HEINBECKER 1961 MCALISTER et coll 1962) However at the present stage of development of selective celiac angiography it was not possible to demonstrate the more minute vascular changes that these methods have revealed

The vascular changes within the tumour bed have been evaluated according to the criteria described Hypervascularity, although found within most neoplasms was also evident in inflammation (Figs 5 and 12) and in cirrhosis of the liver Luminal irregularities and irregular accumulation of the contrast medium are characteristic of neoplasms but these must be unequivocally demonstrated This was in agreement with the operative and decade and mic oangiographic findings of MARGULIS et coll (1960) and MCALISTER et coll (1962) However even in large lesions the number of abnormal vessels was small in relation to the size of the tumour mass On the other hand only one patient had no obvious tumour vessels The lesion in this instance was the smallest (2 5 cm) in the series and the accumulations of contrast medium that formed corresponded to the local limits of the tumour evident in the upper



Fig 12 Woman aged 61 Subtotal gastrectomy (Billroth I) performed 4 years previously for ulcerating adenocarcinoma a) Follow up gastrointestinal study revealed ulceration in gastric remnant b) c) Hypervascularity of fornix without tumour vessels or irregular accumulation Hard mass found at exploration thought to be tumour but repeat upper gastrointestinal study shortly after suggested healing ulceration Two years later the patient was in good health and a further repeat barium study revealed no ulcer or malignant infiltration

gastrointestinal studies The hypervascularity sometimes present in non neoplastic processes persisted throughout both the arterial and venous phases and resulted in a homogeneous collection of contrast medium, difficult to differentiate from that obtained in a neoplasm

The evaluation of the thickness of the wall of the stomach as an index of disease by measuring the distance between the right gastroepiploic artery and the mucosa was not usually of value This vessel has a variable position in relation to the mucosa which is further affected by the degree of gastric distension, the presence of peristalsis, and the roentgenographic projection

Benign gastric tumours exhibited the same vascular changes as the malignant The presence of a smooth outline of the accumulated medium in the tumour was helpful in the differentiation The two sarcomas also had smooth contours but these were more extensive lesions

Particularly encouraging was the ability to demonstrate local and distant extension of the primary tumour Involvement of the liver, hepatoduodenal ligament, and the splenic hilum were readily recognized by angiography Omental extension was often considered likely and later found at operation, but the vascular changes could not be definitely separated from those of the primary tumour Extension to the pancreas, retroperitoneal area, diaphragm, and abdominal wall were poorly outlined angiographically

It is therefore evident that the angiographic changes in gastric neoplasms are difficult to demonstrate and that an improvement of the angiographic technic is needed Methods of improving angiography of the celiac artery in diagnosing diseases of the stomach begin with careful attention to the proper

positioning of the patient based on the gastrointestinal study, so that the involved area is shown in profile Adequate dilation of the stomach is also helpful in separating the vessels so that smaller vascular changes may be appreciated A larger catheter may be used in the celiac artery to deliver a larger bolus of contrast medium at a greater injection pressure (ODMAN 1958) Perhaps a better method to achieve these results is to increase, when possible, the selectivity of the catheterization A combination of these two factors might be helpful for it is unlikely that the left gastric artery can be consistently catheterized Various pharmaceutical agents may be employed in an effort to dilate the smaller vessels to facilitate their demonstration (ABRAMS, BOIJSEN & BORGSTROM 1962, JACOBSON 1963 ABRAMS 1964)

Selective celiac angiography has a definite function as a *complement* study to the barium meal examination in the evaluation of *gastric neoplasms* Even though the vascular changes were small luminal irregularities and irregular accumulation of contrast medium when unequivocally present were characteristic of neoplasms The differentiation of intrinsic from extrinsic gastric lesions was made by delineating the origin of the vascular supply to the tumour The most essential contribution was the demonstration of adjacent and distant extension this being of considerable value in determining the operability of the lesion Although there are still inadequacies in the technique it can be a valuable clinical tool

Acknowledgement

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SUMMARY

Thirty-one patients with benign and malignant tumours of the stomach were examined by selective celiac angiography *in six of the* patients supplemented with selective superior mesenteric angiography to determine the *value of the* methods in the differential diagnosis Benign and malignant conditions could not be *differentiated* but local and distal extensions of the primary tumour were often revealed

ZUSAMMENFASSUNG

Ein und-dreissig Patienten mit benignen und malignen Tumoren des Ventrikels *wurden* mittels selektiver Angiographie der A coeliaca untersucht, bei sechs Patienten wurde ausserdem eine selektive Angiographie der A *mesenterica cranialis* vorgenommen um den differentialdiagnostischen Wert der Methode zu bestimmen Gutartige und bosartige Zustande konnten nicht voneinander unterschieden werden *jedoch konnte* die lokale Ausbreitung des Primar tumors oft bestimmt werden



Fig 12 Woman aged 61 Subtotal gastrectomy (Billroth I) performed 4 years previously for ulcerating adenocarcinoma a) Follow up gastrointestinal study revealed ulceration in gastric remnant b) c) *Hypervascularity of fornix without tumour vessels or irregular accumulation* Hard mass found at exploration thought to be tumour but repeat upper gastrointestinal study shortly after suggested healing ulceration Two years later the patient was in good health and a further repeat *barium study revealed no ulcer or malignant infiltration*

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Thirty-one patients with benign and malignant tumours of the stomach were examined by selective celiac angiography, in six of the patients supplemented with selective superior mesenteric angiography, to determine the value of the methods in the differential diagnosis. Benign and malignant conditions could not be differentiated, but local and distal extensions of the primary tumour were often revealed.

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RÉSUMÉ

Trente et un malades atteints de tumeurs bénignes et malignes de l'estomac ont été examinés par angiographie sélective coeliaque complétée chez six de ces malades par angiographie sélective mésentérique supérieure pour étudier la valeur de ces méthodes pour le diagnostic différentiel. Il a été impossible de distinguer entre affections malignes et bénignes mais cet examen a souvent révélé des extensions locales et éloignées de la tumeur primitive.

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POSSIBILITIES OF ANGIOGRAPHY DURING TEMPORARY OCCLUSION OF THE AORTA IN MAN

by

BJÖRN NORDENSTRÖM and GUNNAR TORNELL

One of the present writers (NORDENSTRÖM 1954) described the appearances of small vascular vessels such as the intercostal and bronchial arteries following the injection of contrast medium above an occlusion of the thoracic aorta in the dog. The very small bronchopulmonary arterial vessels that are considered of importance for *inter alia* the blood supply to malignant tumours might possibly also be examined by this method in human subjects.

Occlusion of the aorta in man has earlier been performed without complications in connection with operations (CRAFOORD 1945) although damage to the spinal cord has also been recorded. Such damage has occurred in operations upon coarctation of the aorta despite the fact that the collaterals are thought to afford possibilities for a more protracted occlusion than when the aorta is normal (BING et coll. 1948). Occlusion of the aorta distal to the origin of the left subclavian artery has also been possible without complications for up to 45 minutes in operations upon aortic aneurysms (BAHNSON 1953, LAM et coll. 1951, COOLEY & DE BAKEY 1955). One subject, however, is reported to have

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had temporary weakness in the legs after a 24 min occlusion of the aorta, and another after a 45 min occlusion.

COOLEY & DE BAKEY considered that the critical time for the spinal cord in connection with aortic occlusion was not established and probably varied from case to case. They observed no parenchymal injuries in abdominal organs or injuries in the lower extremities.

A survey of the literature suggests that it should be possible to occlude the descending aorta for at least 10 min and the abdominal aorta for 15 to 20 min without undue risk to the spinal cord or parenchymatous organs. These periods of time are more than sufficient for the injection of contrast medium and the examination.

Injuries to the human spinal cord in connection with aortography have been described. ANTONI & LINDGREN (1949) performed translumbar aortography with the patient in the prone position on a pillow to compress the abdomen. The aorta was punctured at the level of the lower margin of the first lumbar vertebra under narcosis, and iodopyracet was injected. Flaccid irreversible paresis in the lower part of the body was present when the patient regained consciousness. Autopsy 3 months later revealed degeneration of the myelin sheaths below L 2.

Injections of contrast medium have sometimes been made above an occluded abdominal aorta, where the aorta has been obstructed by arteriosclerotic changes. Paresis has been observed after such an examination (GROSSMAN 1958).

A further 10 to 50 cases of injury to the spinal cord in association with injection of contrast medium into the aorta have subsequently been reported. Descriptive accounts of about half of these have been given by MCAFEE (1957), and KILLEN et coll. (1960).

It would appear that injections of contrast media have generally been made in or very close to arteria radicularis magna, which partly supplies the spinal cord at the level of L1 and L2. Contrast media of the sodium acetrizoate type have frequently been injected, often repeatedly, in high concentration and in large doses, sometimes during slow circulation.

Injuries other than those to the nervous system have also been described. Impairment of renal function may occur especially if the aorta is occluded distally to the origin of the renal arteries, or if selective renal angiography is performed. The dose of contrast medium must then always be diminished (ALWALL et coll. 1955, LODIN et coll. 1955, EDLING et coll. 1957, CRAWFORD et coll. 1957, MCAFEE 1957 and 1961, OLSSON 1961.)

The same rules are valid for gastrointestinal complications following aortography (MCAFEE 1957). Damage and even a fatal outcome have been described

after iodopyracet 70 % (FINEBERG et coll 1958) The risk is increased at selective angiography of the coeliac and superior mesenteric arteries ODMAN (1958) stated that he injected about 1 ml/kg bodyweight sodium diatrizoate (Urografin) 45 % 60 % and 76 % in his patients without causing impairment of the liver function The risk ought to be less if the same amount of sodium diatrizoate is injected into an aorta that is temporarily occluded below the coeliac artery than when it is injected selectively

Temporary occlusion of the abdominal aorta with a balloon catheter and injection of the contrast medium above the occlusion has been performed in 4 patients by OWNIS (1955) the catheter was introduced from the femoral artery Temporary balloon occlusion of the ascending aorta with injection of contrast medium above the aortic valves has been performed by DOTTER (1959) for angiography of the coronary arteries NEYAZAKI (1962) used temporary balloon occlusion of the aorta for bronchial arteriography but he did not discuss the possible risk of contrast media CLIFFTON et coll (1963) for perfusion of the bronchial arteries in 7 patients also occluded the aorta No neurologic complications occurred No toxic damage due to the contrast medium appears to have been observed in these examinations

Certain conclusions may be drawn from the above reports Occlusion of the aorta if prolonged may in itself give rise to complications A further risk is entailed particularly to the spinal cord if the contrast medium is injected above the occlusion

Temporary occlusion of the aorta with two injections of 1 ml/kg bodyweight of iodopyracet 70 % above the occlusion was performed (NORDENSTROM 1954) on one dog without production of any injuries A series of investigations in dogs and cats were therefore undertaken in order to ascertain the limit of the tolerance of the spinal cord to a contrast injection above a temporarily occluded thoracic aorta These investigations cover studies of the toxicity of different contrast media (LINDGREN et coll 1958 KAGSTROM et coll 1960) and direct control of the effect of the injection of these media in different volumes and concentrations above an occluded thoracic aorta These last mentioned studies comprise experiments in fifty six dogs The results disclosed that sodium methylglucamine diatrizoate was the least toxic medium One ml/kg bodyweight Urografin 76 % may be injected into the thoracic aorta of the dog above a balloon occlusion of the aorta for 2 to 3 min without any obvious injury Two such injections on the other hand cannot be performed at one and the same examination (TORNELL 1963) The toxicity of the contrast media has been found to decrease rapidly with decrasing concentration thus a reduction in the concentration of Urografin from 76 % to 60 % implies a marked increase in the safety margin It is considered (KILLEN

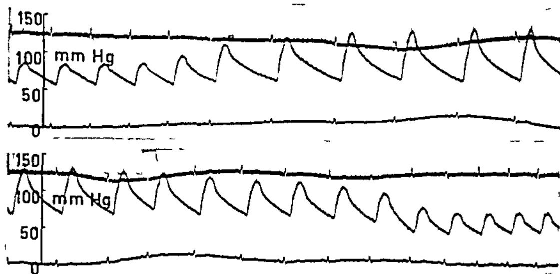


Fig. 1. Occlusion of aorta at level of Th 8. Systolic and diastolic blood pressures as well as pulse pressure above the occlusion increased; moderate bradycardia; the pressures fall on termination of the occlusion. Time marking 0.1 second.

et coll. 1962), moreover, that the tolerance to the majority of contrast media is greater in man than in dog.

All these reasons have suggested the possibility of injecting up to 60 % Urografin above an occlusion of the thoracic aorta. The total volume of contrast medium must of course not exceed 1 ml/kg bodyweight, and only one injection is permissible. The occlusion period for the aorta might also be reduced, as compared with the experiments in animals, and need not exceed a minute. A preliminary investigation has therefore been performed. Particular attention was paid to the patients' subjective reactions to the occlusion and the contrast injection into the aorta, as well as to the changes in blood pressure above the occlusion.

Material and Methods. The investigations were carried out in 8 patients, examined before operation for probable malignant growths.

The occlusions of the aorta were performed with the help of double lumen balloon catheters, with one canal for the inflation of the balloon and another for the injection of contrast medium proximally to it. The construction and shape of the catheter correspond to those of the type previously described (NORDENSTROM 1954).

The left radial artery was exposed and incised under local anesthesia, and the catheter was introduced into the descending aorta. Occlusion of the aorta was effected by filling the balloon with iodopyracet (Umbradil) 35 %, or

Table

Changes in blood pressure above the balloon in connection with temporary occlusion of the human aorta

Case	Sex	Age	Occlusion at level of	Blood pressure								
				Before occlusion			During occlusion			Immediately after		
				Syst	Diast	Mean	Syst	Diast	Mean	Syst	Diast	Mean
1 Occl I	♂	55	Th 8	109	59	83	125	79	105			64
Occl II				95	50	70	110	55	97	65	30	47
2 Occl I	♂	48	Th 7	110			125			65 95 after 1 min		
Occl II				130			160			80 115 after 1 min		
3 Occl I	♀	37	Th 8	95			130			75		
Occl II				110			150			95		

sodium diatrizoate (Urografin) 45 % about 30 to 40 ml of the contrast medium was required

The patients were carefully questioned about their reactions to the occlusion The blood pressure was in 3 cases recorded above the balloon before during and immediately after the occlusion which lasted for about a minute The pressure was recorded with a Tybjaerg Hansen pressure recording apparatus, and the medial axillary line was taken as a point of reference for the recording

After recording the pressures the aorta was again occluded and contrast medium was injected above the occlusion 0 5 ml/kg bodyweight iodopyracet (Umbradil) 35 % was introduced in 5 cases with a manual syringe ad modum Jonsson and about 0 8 ml/kg bodyweight sodium diatrizoate (Urografin) 60 % in 3 cases with a Gidlund automatic syringe at 4 kg pressure The injections were performed in the course of about 2 seconds only one being given at one and the same examination Immediately after the injection the balloon was exsufflated the catheter was removed and the radial artery sutured or ligated

Results and Discussion

Symptoms during the procedure have been surprisingly slight and have consisted of a pulling sensation in the elbow where the catheter had been fixed synchronous with the pulse and slight knocking sensations in the head during the first part of the occlusion Two patients had a vague sensation of cold and heaviness in the lower part of the body and one patient complained of a pounding sensation in the legs at the termination of the occlusion



Fig 2 When injected during temporary occlusion of the aorta the contrast medium can be directed to the small branches In this case the bronchial artery to the right lower pulmonary lobe has been filled it is very narrow and runs down to a rounded mass in the lobe Some small vessels in the periphery of the formation have also been filled from this artery (The mass proved to be a tuberculoma)

Measurements of the pressure in the aorta have shown the same general changes as were earlier observed in experiments in animals (NORDENSTRÖM 1954) The blood pressure in the aorta above the occlusion first rises, the systolic and diastolic pressures, as well as the pulse pressure, increase, and a certain degree of bradycardia occurs On termination of the occlusion the systolic and diastolic pressures as well as the pulse pressure first fall, and then, within a minute or so, return to normal

Fig 1 shows the rise in blood pressure during occlusion of the thoracic aorta (upper curve), and the return of the pressure to normal on termination of the occlusion (lower curve) in Case 3

The changes in blood pressure in the aorta in 3 cases, in each of which two

occlusions were performed, are presented in a Table The values represent the average systolic and terminal diastolic pressures and the mean pressures The systolic pressure is seen to have risen to a relatively high level in Case 3 during the occlusions or by about 35 % of the initial pressure The relative rise in pressure in the other two cases was less The return of the pressure to normal in Case 3 was recorded within a minute from the termination of the occlusion

Injections of contrast medium were given above the occlusion in all the eight cases examined The aorta was occluded at the level of Th7 in one case Th8 in two cases Th9 in one case Th11 in one case Th12 in one case and at the level of L1 in two cases

Angiography (Case 3 in the Table) during temporary occlusion of the aorta at the level of Th8 for a probable tumour of the lower lobe of the right lung is shown in Fig 2 The contrast medium has passed to the bronchial artery of the right lower lobe which appears to be normal in width some of the vessels surrounding the tumour were then filled and smaller bronchial arteries on the left side were also outlined Subsequent operation revealed that the mass was a tuberculoma Small vessels especially the intercostal arteries and their branches as well as bronchial arterial branches of thread like caliber were also observed in the other cases

Thrombosis was produced in the radial artery by the catheterization in two cases The pressure of the blood column upon the balloon catheter gives it a piston like movement due to its fixation at the elbow This movement is transmitted particularly to the subclavian axillary and brachial arteries It was possible to scrape out a number of clots from the radial artery via the incision after the catheter had been removed good pulsations were present in the artery following its suture Spasms of the brachial artery that occurred with the introduction of the catheter were successfully treated with sodium acetrizoate These cases have been described earlier (LINDGREN et coll 1959)

Conclusions

Temporary occlusion of the aorta seems to occasion only slight discomfort The occlusion produces relatively moderate tachycardia and an *increase of* both the systolic and diastolic pressures These sink to subnormal values following the procedure quickly to return to normal

It appears possible to perform aortography with injection of the contrast medium above the occlusion so that small vessels arising from the aorta such as intercostal and bronchial arteries may be filled Since it is possible to attain a very high concentration of the contrast medium in these vessels



Fig 2 When injected during temporary occlusion of the aorta the contrast medium can be directed to the small branches In this case the bronchial artery to the right lower pulmonary lobe has been filled it is very narrow and runs down to a rounded mass in the lobe Some small vessels in the periphery of the formation have also been filled from this artery (The mass proved to be a tuberculoma)

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particular attention must be paid to the toxic effect of the contrast medium, above all upon the spinal cord. Earlier investigations in dogs have indicated that not more than one injection of contrast medium during a brief temporary occlusion of the aorta should be performed if Urografin is the medium employed. The concentration and volume of contrast medium proven to fall within the limits of tolerance in the experiments performed in dogs should moreover be reduced in order to increase the margin of safety. Not more than 1 ml/kg body weight of Urografin 60 % should be injected. The period of occlusion for the aorta should be as short as possible and need not exceed one minute.

It was possible to deal with thrombosis arising in the left brachial artery in two cases and with spasm in the brachial artery in a further two cases without any lasting harmful effect. These complications may have been due to a mechanical effect, as after inflation of the balloon the catheter moved synchronously with the heart beat, causing damage to the intima of the vessels or producing spasm. This risk cannot be counteracted with the present catheterization technique. No further attempts have therefore been made to occlude the aorta with catheterization via the radial artery, although the occlusions as such, with injection of the contrast medium above the occlusion, were well tolerated by the patients.

SUMMARY

Aortography was performed by injection of contrast medium above an occlusion of the thoracic aorta obtained by balloon catheterization in 8 patients. Numerous small intercostal and bronchial arteries were outlined. The value of the method in pulmonary lesions is discussed.

ZUSAMMENFASSUNG

An 8 Patienten wurde eine Aortographie nach vorherigem Verschluss der thorakalen Aorta durch einen aufblasbaren Katheter vorgenommen. Zahlreiche Interkostalarterien sowie Bronchialarterien fullten sich. Der Wert der Methode bei Lungenerkrankungen wird besprochen.

RÉSUMÉ

Les auteurs ont pratiqué sur 8 malades des aortographies avec injection du moyen de contraste au dessus de l'obstruction de l'aorte thoracique par un cathéter à ballonnet. De nombreuses petites artères intercostales et bronchiques ont été rendues visibles. Les auteurs examinent l'intérêt de cette technique pour les lésions pulmonaires.

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RETROPERITONEAL FIBROSIS

by

JURI KAUDE

Excessive proliferation of fibrous tissue of known or unknown origin in the retroperitoneal space has been described as periureteritis plastica sive obliterans stenosing, idiopathic periureteritis, perirenal or Gerota's fascitis, periureteral fibrosis, sclerosing retroperitonitis, Ormond's syndrome and periaortic fibrosis. The term "retroperitoneal fibrosis", as used by DINEEN et coll. (1960), would appear to be the most suitable one and will be employed in this paper.

ALBARRAN (1905) was probably the first to describe ureteral obstruction due to fibrotic changes in the retroperitoneal space. BACHRACH (1928) distinguished two groups of the condition: periureteritis fibrolipomatosa, corresponding to a generalized retroperitoneal fibrosis, and periureteritis fibrosa, a local form limited to the periureteral region, described later by VEST & BARELARE (1953) as periureteritis plastica.

PERARD & ORSINI (1937) as well as RISCHAR (1937) reported further cases. LEBBIN (1942) and DIECKOW (1942) described peripyelitic fibrous changes that might be considered as a variety of localized retroperitoneal fibrosis. ORMOND (1948) published two cases of bilateral ureteral obstruction due to envelopment and compression by an inflammatory retroperitoneal process. Approximately 100 cases have since then been reported. The purpose of this

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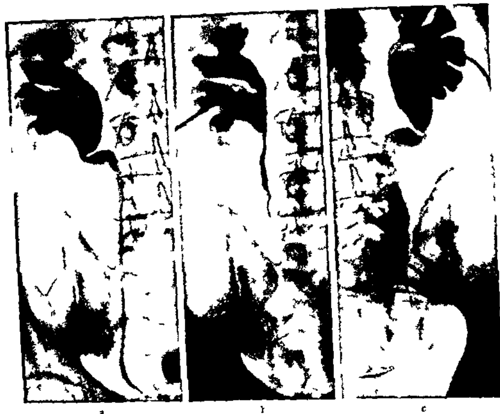


Fig 2 Case 2 Retroperitoneal fibrosis a) Right pyelography Infiltration and medial deviation of ureter Hydronephrosis b) Right antegrade pyelography six months after roentgenogram (a) The disease has advanced complete obstruction of ureter c) Left antegrade pyelography Hydronephrosis and dilatation of the proximal and middle parts of ureter with compression of distal part Only a small amount of the medium reaches the bladder

the spleen being entirely embedded by sclerotic tissue The patient complained of severe pain in the chest

Roentgen examination disclosed a homogenous mediastinal mass which was thought to represent extension of the fibrosis (Fig 1)

When the patient was last seen the urinary output was over two litres daily and the blood NPN level about 100 mg/100 ml The serum electrolytes were normal the hemoglobin was only about 8 g per cent and the blood sedimentation rate was constantly high i e 125 to 145 mm per hour B P 150/100 She had occasional attacks of pyelitis

Case 2 Male aged 64 admitted with advanced retroperitoneal fibrosis He had had chronic otitis since the age of 2 years orchitis following parotitis and toxic struma At an accident contusion of the left thigh had occurred He had been treated for substernal pain considered to be angina pectoris a year before admission to our hospital he had also suffered from lower back pain and had been ordered to wear a support On admission moderate anemia

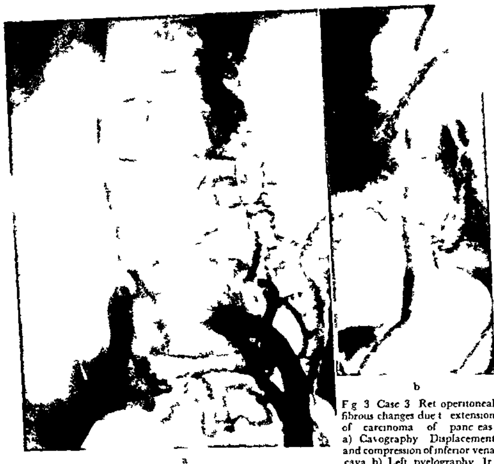


Fig. 1. Case 1. Retroperitoneal fibrosis. Mediastinal involvement by ascending retroperitoneal fibrosis.

paper is to discuss important etiologic features and the roentgen diagnosis, two cases of 'idiopathic' retroperitoneal fibrosis with an unusual extension of the changes are reported to illustrate the difficulty in arriving at a correct diagnosis.

Case reports

Case 1. Female, aged 56, who had undergone appendectomy in 1953. Operation in 1955 had disclosed a fibrous tissue mass around the right ureteropelvic junction. This was believed to be malignant and the right kidney was removed. The histopathologic examination revealed, however, retroperitoneal fibrosis with marked predominance of pseudoxanthomatous cells. A similar process developed a year later in the corresponding region on the left side and a transparenchymatous anastomosis between a dilated renal calyx and the ureter distal to the stenosis was performed. This functioned well for five years but impairment of renal function led to nephrostomy and later to explorative laparotomy. Thereafter, anuria developed and she was treated with an artificial kidney. At the latest operation, it was found that the disease had advanced and that the retroperitoneal fibrous masses extended from the pelvis to the diaphragm



a b

Fig 3 Case 3 Retroperitoneal fibrous changes due to extension of carcinoma of pancreas a) Cavography Displacement and compression of inferior vena cava b) Left pyelography Irregular stenosis of ureter

Owing to decreasing urinary output left pyelostomy was performed The lower pole of the kidney and the proximal part of the ureter were embedded in dense fibrous masses fibrosis as well as low differentiated cancer cells were demonstrated histologically in the fat tissue Subsequent right pyelostomy revealed a similar condition on the other side

It was apparent that the whole of the retroperitoneal space was involved The findings were confirmed at autopsy a month later The process enveloped and compressed but did not obliterate the main abdominal vessels nor ureters and extended from the liver pancreas and kidneys into the pelvis and inguinal regions It was verified histologically that the fibrotic changes were due to metastases from a carcinoma of the pancreas

Discussion

Pathologic features Retroperitoneal fibrosis may be diffuse local or segmental and although not invasive involve the aorta the inferior vena cava the common iliac vessels kidneys and one or both ureters Usually but not necessarily

high BSR and elevated blood NPN serum electrophoresis revealed changes consistent with an active chronic process

Roentgen examinations of the gallbladder stomach heart and lungs spine pelvis and lower extremities were negative

Urography (after the NPN had been brought to normal) showed no excretion on the left side the right renal pelvis and upper part of the ureter were dilated (Left pyelography had to be abandoned since it was impossible to pass the catheter)

At operation extensive retroperitoneal fibrosis was present it was confirmed histologically The left ureter and iliac vessels were enveloped by a mass of sclerotic connective tissue

Postoperative urography disclosed as previously a non functioning left kidney and hydronephrosis on the right side Attempts to pass a catheter into the left ureter failed

Right pyelography Considerable right hydronephrosis together with medial deviation and irregular narrowing of the ureter at the level of the fourth lumbar vertebra were noted (Fig 2a)

Selective nephro angiography demonstrated marked bilateral dilatation of the pelves and atrophy of the renal tissue

Left pyelostomy was performed Postoperative *left antegrade pyelography* disclosed obstruction in the distal part of the ureter and only a small amount of contrast medium passed into the bladder (Fig 2c) Bilateral ureterolysis and ureterocystoneostomy revealed that the fibrosis descended below the sacral promontory and considerable pericystic sclerosing adhesions were present less advanced changes were evident on the right side Some weeks later right pyelostomy as well as closure of a colic fistula had to be performed The hydronephroses then decreased in size and the urinary output through both the pyelostomies was satisfactory The blood NPN was normal and the patient was returned to the referring hospital

Case 3 Male aged 65 previously operated for a benign polyp in the descending colon with pain in the right iliac fossa radiating to the scrotum pollakisuria and loss of weight The routine laboratory examinations were within normal limits electrophoresis suggested changes due to an active chronic process

Roentgen examinations of the stomach spine and the right hip were negative cholecystography revealed a solitary biliary calculus and a barium enema disclosed diverticulosis but no tumor or colitis Urography selective nephro angiography and tomography of the kidneys demonstrated renal fibrolipomatosis (OLSSON & WEILAND 1963)

Two months later the patient returned to the hospital with an acute attack of cholecystitis and was operated upon an inflamed gallblader containing a solitary calculus was removed The BSR was now high (up to 90 mm per hour) moderate anemia but the white blood cell count was normal Electrophoretic changes suggested malignant disease No proteinuria was present the urinary output NPN and serum electrolytes were normal The patient had considerable pain in the left lower abdomen and had lost much weight

Cavography was performed and displacement and compression of the inferior vena cava from the second to the fifth lumbar vertebra was demonstrated (Fig 3a) Non functioning left kidney had been demonstrated by urography the excretion was delayed and marked hydronephrosis was present on the right side It was concluded that a retroperitoneal mass was producing displacement and compression of the inferior vena cava and both ureters Ureteral catheterization could be performed easily on the left side a slight resistance was felt in the right ureter

Left pyelography revealed marked dilatation of the pelvis ureteral stenosis at the level of the innominate bone (Fig 3b)



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Discussion

Patholo ic features Retroperitoneal fibrosis may be diffuse local or segmental and although not invasive involve the aorta the inferior vena cav the common iliac vessels kidneys and one or both ureters Usually but not necessarily

it arises in the midline, near the bifurcation of the aorta and extends laterally. According to HACKETT (1958) the lesion never crosses a line running one centimetre laterally to the ureter. It does not often ascend above the level of the kidneys although compression of the common bile duct (RAPER 1956), envelopment of the pancreas, spleen (SAMELLAS 1961, and Case 1 in this paper), colon and megacolon (SIMEONI & ALFIERI 1958) and the adrenals (PAULL et coll. 1955, MAPCOLES & McQUEENEY 1960) have been reported. Concomitant mediastinal fibrosis is rare (TUBBS 1946, PARTINGTON 1961, and Case 1 in this paper), periarterial fibrosis of coronary arteries has been described (REED & STANLEY 1959).

The process seldom extends below the sacral promontory (RAPER 1956, GOTZEN 1960) although it may start in and be limited to the pelvis and the pericystic region (HEWETT & HEADSTREAM 1960, POPHAM & STEVENSON 1960). An unusual caudal extension of the lesion below the pelvic brim and into the space around the bladder was evident in the present Case 2, the process even descended into the inguinal region in Case 3 but the fibrosis was secondary to metastasis.

Fibrotic, sparsely cellular connective tissue of variable density dominates the histologic appearances. Areas of fat are enclosed by the fibrosis and a slight or moderate inflammatory infiltration of lymphocytes, plasma cells, eosinophiles and occasional neutrophiles is present.

Age and sex distribution. About two thirds of the cases reported of so called 'idiopathic' retroperitoneal fibrosis are males. There is a prevalence for the fourth to sixth decade but the condition may occur at practically any age. The youngest case reported was a girl of 9 years (WEINER & BATTKE 1962) and the oldest a man of 75 (KNOWLAN et coll. 1960).

Symptomatology. The variety and vagueness of the symptoms and signs, as in Case 2, is characteristic of retroperitoneal fibrosis. The onset of the condition is usually insidious and usually occurs over a period of some weeks or months, seldom over one or more years. The onset may sometimes be as brief as two or three days and the clinical picture may suggest an acute abdominal condition (THOMPSON et coll. 1961).

The most common complaint is flank, back or abdominal pain, usually of a dull character but sometimes resembling acute renal colic or suggesting gastroenteritis, cholecystitis, pancreatitis or appendicitis. The pain is often of an intermittent character, being aggravated by recumbency and relieved by flexion of the lumbar spine (MILLARD & WYMAN 1959). It may be intensified by alcohol (HACKETT 1958, PARTINGTON 1961) and localized to the epigastrium (RAPER 1956) or substernally (ORMOND 1948). In Case 1 severe chest pain developed, probably caused by the fibrosis ascending into the mediastinum.

Unnecessary therapeutic measures and operations have been undertaken due to the character of the pain suggesting other conditions The following variety of symptoms and signs have been recorded in about 100 cases of retroperitoneal fibrosis

General symptoms Loss of weight (often considerable), anorexia, nausea fatigue thirst fever, arthralgia Physical examination often reveals tenderness in the costovertebral angle, either on one or both sides

Signs referable to the cardiovascular system Leg pain of claudication nature edema and elephantiasis of the lower extremities periorbital and scrotal edema The blood pressure may be normal or elevated Pericardial friction has been recorded (RAPER 1955)

Gastrointestinal signs Mucous stools and melaena diarrhea or constipation excessive flatulence, vomiting and icterus due to obstruction of the hepatic duct (RAPER 1956) A mass may be palpable in the abdomen or the pouch of Douglas

Genito urinary signs Sudden and complete anuria may occur On the other hand polyuria and polydypsia suggesting diabetes insipidus have been ob served (KNOWLAN et coll 1960 TWIGG Jr 1960) A hydrocele is frequently present

Laboratory findings Anemia is evident in approximately 50 per cent of cases The white blood cell count is usually within normal limits but may occasionally be considerably elevated The BSR is sometimes normal but may be extremely high Electrophoresis reveals changes similar to those found in an active chronic process (LUND & PEDERSEN 1959, Case 2 of this paper) The urine is often completely normal but proteinuria hematuria and pyuria may be present the specific gravity is low in advanced cases with secondary hydronephrosis and poor renal function The blood NPN is normal or elevated, depending on the renal function

Roentgen appearances The most significant changes in retroperitoneal fibrosis are related to the kidneys and urinary tract, although other organs may be involved either primarily or secondarily

Examination of the chest may reveal changes in the pulmonary parenchyma or pleura Involvement of the mediastinum was evident in Case 1 Only two cases of concomitant mediastinal and retroperitoneal fibrosis appear to have been previously reported (TUBBS 1946 PARTINGTON 1961)

Urography The disappearance of outlines notably of the psoas and lumbo sacral muscles may be observed in the preliminary films (MILLARD & WYMAN 1959 TWIGG Jr 1960) Urography may produce normal findings in the early stage of the condition (THOMPSON JR et coll 1961) Retroperitoneal changes although present do not yet affect the urinary system by compression of the

ureters. Medial deviation of one or both ureters (Fig. 2, a and c), caused by the process extending laterally from the midline, is an early and typical sign (GOTZEN 1960, THOMPSON JR et coll. 1961, and others).

An irregular cone formed stenosis caused by ureteric compression may develop in the more advanced stages (Fig. 2c), this may end in complete obstruction (Fig. 2b). The compression in the majority of cases lies at the level of the fourth and fifth lumbar vertebrae, but any part of the ureter may be involved. The region engaged may be short, but the process may also envelop the whole of the ureter with the exception of its terminal part (RAPER 1956). A variable degree of dilatation of the ureter and renal pelvis is present above the stenosis. The changes may be uni- or bilateral. The other side is often affected some time later, the function and morphology of one kidney in these cases is normal in the early stage of the disease, while ureteric stenosis with secondary hydronephrosis is present on the opposite side. Delayed excretion of the medium on the side first affected, or loss of renal function, is evident at repeat urography with progress of the disease, and stenosis on the other side appears. Pyelonephritic changes are often present. STOSSEL & RIMPAU (1958) have described varicosis of the ureteropelvic junction and proximal part of *the ureter resulting from retroperitoneal fibrous changes.*

The renal function in less advanced cases improves and the secondary hydronephrosis gradually diminishes after treatment, usually operative. A complete restitution of renal function and the morphologic appearances is possible (ROSS 1958, HAWK & HAZARD 1959, KNOWLAN et coll. 1960).

Pyelography in cases in which catheterization is possible will demonstrate the morphologic changes. Pyelography occasionally fails to reveal any sign of ureteral compression in spite of advanced engulfment of the ureters (MARGOLES & MCQUEENEY 1960).

Angiography of the main abdominal vessels is advisable in the presence of clinical signs of arterial occlusion or impaired venous backflow and to judge *potential renal function. Narrowing of the aorta and the common iliac arteries* has been reported by HACKETT (1958). Selective nephro-angiography demonstrated marked hydronephrosis and atrophy of the renal tissue in Case 2. Involvement of the inferior vena cava may be verified by cavography (*Fig. 3a*).

Etiologic considerations. ORMOND (1948, 1960) and a number of other writers were inclined to believe that, apart from the secondary fibrosis due to trauma, malignancy or inflammatory processes of the lower bowel and urinary tract, a new clinical entity, so called "idiopathic" retroperitoneal fibrosis of obscure etiologic origin exists. STELZNER (1960) and BROSIG (1960) on the contrary considered that in practically all cases some previous lesion or disease is present and may be responsible for the development of retroperitoneal fibrosis.

TWIGG Jr (1960) and KNOWLAN et coll (1960) pointed out the frequency of pyelonephritic changes in cases of retroperitoneal fibrosis Long standing infections of the lower intestinal tract may be the underlying etiologic factors in a retroperitoneal inflammatory process and fibrous reaction, resulting in urologic disease (COPPRIDGE et coll 1955 IOZZI & MURPHY 1957 and others)

Retroperitoneal fibrosis has also been observed secondary to other inflammatory conditions such as pancreatitis and non tuberculous spondylitis (BROSIG 1960) thrombophlebitis of iliac and pelvic vessels (VINCENT & NAGY 1961) renal tuberculosis of the opposite kidney (MACLEAN 1954) and lymphopathia venereum (DOUGHERTY 1955) Some cases are probably due to reflux from the renal pelvis via the sinus and hilum into the perirenal tissue (OLSSON 1962) Evidence has actually been produced that peripelvic urinary extravasation may be responsible for fibrous reaction of the retroperitoneal tissue (HAMPERL 1949 and others) LANDES & HOOKER (1952) observed retroperitoneal fibrosis following extravasation of aqueous urographic contrast media in connection with pyelography

Previous surgical interventions in the lower abdomen or retroperitoneal space (ALBARRAN 1905 STELZNER 1960) and traumatic lesions (GOTZEN 1960) as well as hemorrhage (HACKETT 1958 KNOWLAN et coll 1960 THOMPSON JR et coll 1961) are apparently able to produce the condition CHARNOCK et coll (1961) reported a large aneurysm of the aorta in the pathologic fibrous tissue OPPENHEIMER & GOLDMAN (1962) observed a case with a perirenal hematoma secondary to renal biopsy producing obstructive periureteric fibrosis It is possible that the fibrous reaction was intensified by the kidney puncture performed in the present Case 3 The condition started one year after appendectomy had been carried out in Case 1

Changes of a retroperitoneal fibrosis type have also been reported in connection with malignant conditions such as reticulum cell sarcoma (TREVER 1958) Hodgkin s disease (KENDALL & LAKEY 1961) adenocarcinoma of the kidney (KNOWLAN et coll 1960) and in carcinoma of the pancreas in the present Case 3 The history however often fails to reveal any previous illnesses or operations of importance These cases may probably be considered as representing idiopathic conditions of undetermined etiologic origin

The histologic relationship of retroperitoneal fibrosis to non suppurative panniculitis has been discussed by DINEEN et coll (1960) HOFFMAN & TRIPPEL (1961) have reported retroperitoneal fibrosis in two cases of generalized arteritis findings consistent with tissue changes occurring in hyperallergic states COPPRIDGE et coll (1955) believed necrosis of fat cells simulating a foreign body reaction to be responsible for the fibrosis LUND & PEDERSEN (1959) classified the disease as a collagenosis HAWK & HAZARD (1959) pointed out a close

resemblance of the gross and microscopic appearances of the retroperitoneal and mediastinal fibrosis to Riedel's struma.

Retroperitoneal fibrosis associated with more or less rare conditions apparently independent of the fibrosis, has been observed. RANNIGER (1961) reported the occurrence of the disease in a case of multiple hamartomas of the lungs, TREVER (1958) in connection with a clinical condition featuring epileptic seizures of the Jacksonian type, arthralgias, hepatosplenomegaly and hyperglobulinemia. POPHAM & STEVENSON (1960) have seen it together with a factor VII deficiency and a carcinoid syndrome. PERARD & ORSINI's case (1937) followed generalized dermatosis. Three cases reported in the literature have occurred in diabetics.

The diagnosis of retroperitoneal fibrosis is not easy due to the great number of atypical symptoms and signs. The final diagnosis has generally been made either at operation or by microscopy, but errors are possible and the lesion may be mistaken for a malignant growth or vice versa. One kidney was removed in the earlier stage of the disease in Case 1, because the fibrous mass was considered to be a malignant tumour. MARGOLIS & McQUEENEY (1960) and HOFFMAN & TRIPPEL (1961) found that carcinoma was reported in frozen sections, a diagnosis that was finally amended to retroperitoneal fibrosis. TREVER's case (1958) was thought to be idiopathic fibrosis before the correct diagnosis of the primary disease, reticulum cell sarcoma, was made by biopsy of lymph nodes from the mesentery. Case 3 was caused by carcinoma of the pancreas but the definite diagnosis was not made until the terminal stage of the disease and confirmed by autopsy.

There are no typical roentgen signs of retroperitoneal fibrosis. Conventional films of the abdomen may occasionally reveal a retroperitoneal mass, or a respiration pyelogram may indicate fixation of the kidneys (HAWK & HAZARD 1959). Medial deviation and irregular stenosis of one or both ureters with secondary hydronephrosis, delayed excretion of the contrast medium or sudden loss of renal function occurring shortly after a normal urography are suggestive findings. Examination of the chest may reveal pulmonary changes, pleural effusion and mediastinal fibrosis. Angiography is helpful to prove involvement of abdominal vessels.

The differential diagnosis includes neoplasms of the kidney and ureter, malignant growths, lymphomas and metastases in the retroperitoneal space. Periarteritis nodosa, non opaque calculi and blood clots in the ureter may simulate ureteral obstruction caused by fibrosis. Intramural endometriosis of the ureter, retrocaval ureter and aortic aneurysms have to be considered.

The treatment of retroperitoneal fibrosis is operative. Steroids have been used by a number of writers and irradiation therapy has also been tried (OPPEN-

HEIMER et coll 1962, HACKETT 1958, BROSIG 1960 and others) LUND & PEDERSEN (1959) treated their case with phenylbutazone with beneficial results

Conclusions

Retroperitoneal fibrosis is produced by inflammatory malignant or traumatic processes An etiologic factor can in many cases not be established The diagnosis is always difficult owing to the great variety of symptoms and signs Radiologic features are not pathognomonic although medial deviation of the part of the ureter involved is a fairly typical finding The final diagnosis is usually made by microscopy

SUMMARY

Two cases of idiopathic retroperitoneal fibrosis with unusual findings are reported A third case of carcinoma of the pancreas producing fibrotic changes in the retroperitoneal space is described Etiologic aspects clinical signs and the roentgen diagnosis of the condition are discussed

ZUSAMMENFASSUNG

Es wird uber 2 Falle von idiopathischer retro-peritonealer Fibrose mit *ungewohnlichem* Befund berichtet Ein dritter Fall von Pankreaskarzinom mit retro-peritonealer *Fibrose* wird ebenfalls beschrieben Die Atiologie die klinischen Erscheinungen und das Rontgenbild der *Erkrankung werden erortert*

RÉSUMÉ

Présentation de deux cas de fibrose rétro-péritonéale idiopathique ayant des signes inhabituels L auteur décrit un troisième cas de *cancer du pancréas* donnant des lésions fibrotiques dans l espace rétropéritonéal Il *examine les caractères étiologiques* les signes cliniques et le diagnostic radiologique de cette affection

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FROM THE ROENTGEN DEPARTMENT (DIRECTOR PROF. P. VIRTAMA), UNIVERSITY CENTRAL HOSPITAL, ÅBO, FINLAND

RECTAL PARIETOGRAPHY IN ULCERATIVE COLITIS

by

P. VIRTAMA

ELIA & JOB (1957) were the first to draw attention to an increase in the presacral space in ulcerative colitis. EDLING & EKLÖF (1960, 1963) and RUDHE (1960) later confirmed the value of this radiologic sign. CHRISTEN & FRY (1963) pointed out that widening of the presacral space, consisting of the rectal wall, lymph glands and fatty areolar tissue, may be caused by conditions such as oedema and malignant deposits. Widening of the presacral space is therefore not always an indication of thickening of the rectal wall. Even if the demarcation contour of the rectal wall and the increased presacral soft tissue layer may sometimes be faintly outlined, the best method of demonstrating the actual thickness of the wall is rectal parietography.

Method and Material. A lateral approach to the presacral space by the technique described by VIRTAMA (1960) was used. Following local anesthesia, a 150 mm needle (O.D. 1.2 mm) was introduced under the sacrum. A thin teflon catheter was pushed through the needle which was then removed. A needle was attached to the catheter and 1 ml Urografin 45 % was injected to confirm the position of the catheter tip in a test film. About 200 to 400 ml

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a b

Fig 1 Normal rectal parietography a) lateral and b) oblique Widening of the presacral space caused by the oxygen injected and partially by a curved sacrum

oxygen were injected through the catheter with the patient lying prone in the Trendelenburg position The rectum was then filled with barium emulsion and occasionally with barium emulsion and air for double contrast Ordinary

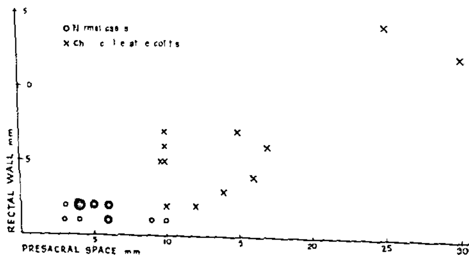


Fig 2 Scatter diagram Width of presacral space as plotted against rectal wall thickness



Fig. 3 Rectal parietography Lateral view Thickened (6 mm) rectal wall and normal presacral space

Fig. 4 a) Widened presacral space mainly caused by thick rectal wall b) Rectal parietography

Fig 3



Fig. 4a



Fig 4b

films were exposed during contrast filling in the postero anterior, lateral and both oblique positions, and the examination was concluded with lateral tomography

The presacral space was measured in the lateral projections of the rectum and sacrum The shortest distance between the dorsal aspect of the barium filled rectum and the ventral surface of the sacrum was measured at the level of S3—S4 The thickness of the rectal wall was measured from the parieto graphic films at the same level

The series examined up to the present date contains 12 cases of ulcerative colitis and a control material of 14 cases examined for probable adrenal tumours All the former underwent rectoscopy and biopsy specimen was obtained in several of them

Results and Discussion

The normal thickness of the rectal wall was never more than 2 mm and varied with the filling stage of the rectum (Fig 1) The correlation between the rectal wall thickness and the width of the presacral space is indicated in the scatter diagram (Fig 2) There was no significant correlation in the control group A relatively wide presacral space was apparently often due to redundant fat tissue or to a curved shape of the sacrum (Fig 1) The presacral space in ulcerative colitis does not necessarily give a correct image of the actual thickness of the rectal wall it was occasionally within normal limits while the rectal wall was notably thickened (Fig 3) The presacral space was always wider in parietography than in the barium enema examination owing to the gas injected

The rectal wall was thickened in clinically and rectoscopically severe cases of ulcerative colitis (Fig 4) An increase in the total distance between the rectum and the sacrum was caused both by oedema and swelling of the adipose tissue and thickening of the rectal wall itself Moreover, in ulcerative colitis the rigidity of the bowel prevents the rectum from distending and in long standing cases shortening of the bowel tends to draw it away from the sacrum as pointed out by CHRISPIN & FRY (1963)

Measurement of the presacral space provides an easy and important preliminary examination in ulcerative colitis but it cannot give all the information needed for surgical intervention Rectoscopy and rectal parietography are therefore recommended for adequate examination of the rectum in these cases

Acknowledgement

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SUMMARY

The rectal wall was demonstrated by injecting oxygen into the presacral space and simultaneously filling the rectum with contrast medium. *Rectal parietography* provides a simple examination method for assessing possibilities for surgical intervention in ulcerative colitis.

ZUSAMMENFASSUNG

Durch Einspritzen von Sauerstoff in den Präsakralraum und gleichzeitige Füllung des Rektums *mit Kontrastmittel wurde die Rektalwand zum Vorschein gebracht. Die rektale* Parietographie ist eine einfache Untersuchungsmethode zwecks Aufzeigens der Möglichkeiten eines chirurgischen Eingriffs bei Colitis ulcerativa.

RÉSUMÉ

La *paroi rectale est mise en évidence par injection d'oxygène dans l'espace présacré et* par remplissage simultané du rectum par un moyen de contraste. La pariétographie rectale constitue une méthode d'examen simple pour juger les possibilités d'intervention chirurgicale dans la rectocolite hémorragique.

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FROM THE ROENTGEN DEPARTMENT (DIRECTOR PROF ERIK LINDGREN) SERAFIMERLASARETTET STOCKHOLM, SWEDEN

CINEROENTGENOGRAPHY WITH EXTREMELY SHORT PULSES

by

OVE MATTSSON

Pulsing was primarily used in cineroentgenography to minimize patient irradiation during periods when no exposures were taking place, in other words during the change-over from one frame to another As the time required for the change-over often amounted to 50 % of the total time a considerable reduction in the patient dose was obtained by camera controlled pulsing without any deleterious effects on the cineroentgenographic results

An exposure time shorter than that achievable with the camera shutter alone may be obtained by shortening the pulses and increasing the radiation intensity correspondingly This produces a reduction in the motion blur in each frame an advantage that is of great value not only in the examination of the individual frames but also for the observation of movement during projection Pulsing systems have been described by HOEFFKEN & JOTTEN (1963) and by BECKER (1963) who have demonstrated their significance for the recording of moving objects whereby among other advantages the apparent deformation which otherwise arises in objects in motion can be avoided Pulse

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durations of an order as low as 1 millisecond are possible. The pulsing units for roentgen machines are as a rule fairly complicated systems.

Pulsing has brought about considerable advances in the field of cineroentgenography. Every opportunity that offers itself for improving the quality of the individual frames should naturally be utilized, and the ability to make the pulses as short as possible constitutes a great advantage.

The Fexitron flash roentgen unit would seem to offer good possibilities for pulsing in connection with cineroentgenographic recording with an image intensifier. It gives pulses that should be strong enough for exposure of a cineroentgenographic frame, and the pulses may be repeated at a relatively rapid rate. The highest pulse number possible at present (25 pulses per second) tallies with the camera speed commonly used in cineroentgenography.

The main features of the Fexitron system have already been presented (DYKE, FLOYD & GRUNDHAUSER 1961, HOWISON, ANDERSON, DYKE & GRUNDHAUSER 1963, and OLIN & CARLSSON 1963). From information supplied by the designer, W. Dyke, after trials made at this hospital, HOWISON on one occasion employed an image intensifier in conjunction with the Fexitron unit, but its use for roentgencinematography was not under consideration at that time.

The Fexitron unit may be said to be nearly ideal as a pulse generator for cineroentgenographic work. The pulse duration of 1/20th of a microsecond meets all requirements. The simplicity of this apparatus in comparison with the complicated stationary equipment ordinarily employed for roentgen pulsing offers considerable advantages. Adjustments in the present design to fit this special purpose may bring even greater gains, and with these in view contact has already been established with the manufacturers, Field Emission Corporation, McMINNVILLE, Oregon.



Series of frames from a cineroentgenographic examination using the Fexitron model 845 together with a Cinelix intensifier. Exposure time for each frame 1/20 000 000 sec.

The Fexitron model 845 was used in our trials together with a Cinelix image intensifying system or with an ordinary image intensifier of the Siemens type A series of frames from a cineroentgenographic examination recorded with a Cinelix intensifier and a frame and pulse rate of 15 per second, is shown in the accompanying illustration The camera and the Fexitron unit had both been set at the same speed and operated without interelectrical contact Synchronization for routine use can be readily achieved The kilovoltage employed was 100 kV and each pulse corresponded to 0 06 mAs

The short pulses produced some surprising observations With the Cinelix intensifier which operates with a fluorescent screen and visual light an afterfluorescence that persisted for several frames (at 25 frames per second) after a pulse had passed was observed A delay in the build up of the image was furthermore noted and single pulses gave a lower exposure yield than a rapidly repeated train of pulses This is probably connected with the first observation as a cumulation of the light output may be said to occur Choice of suitable fluorescent screen materials will in all probability succeed in completely eliminating these disadvantages An insignificant yet fully noticeable after glow was observed when an ordinary image intensifier was used

Because of its simplicity and the short pulses the Fexitron system will probably prove to be a valuable aid in cineroentgenography It would be a considerable advantage if image intensifiers and pulse generators could be modified to meet cineroentgenographic requirements

SUMMARY

The use of the Fexitron flash roentgen unit in the cineroentgenographic field is discussed and examples of its application are presented

ZUSAMMENFASSUNG

Die Anwendungsmoglichkeiten eines Fexitron Rontgenblitzapparates fur das Gebiet der Röntgenkinematographie werden besprochen und Beispiele der Anwendung angefuhrt.

RÉSUMÉ

L auteur étudie l emploi du générateur pulsatoire Fexitron en radiocinéma et donne des exemples de son application

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VASOPRESSIN ACTION ON THE CEPHALIC VASCULATURE

Angiographic study in the dog

by

KARL FREDRIK ARONSEN and GORAN NYLANDER

Hydrostatic forces and the rigidity of the skull were formerly thought to be the only two factors concerned with the regulation of cerebral blood flow The control of blood flow was consequently considered to be largely passive and subject to fluctuations in the systemic blood pressure However, the modern concept of this problem suggests that both neural and hormonal factors are involved in the regulation of the cerebral blood flow Further evidence indicates that a cerebral circulatory response i e vasodilation or vasoconstriction may also occur in response to different pharmacologic agents (LASSEN 1959 SOKOLOFF 1959 GOODMAN & GILMAN 1960 and BOVET 1961)

ARONSEN & NYLANDER (1964) in a preliminary report of common carotid angiography in the dog showed that intravenously administered vasopressin markedly alters the distribution of blood flow within the carotid arterial system, as judged by cerebral angiography The flow of contrast medium through the

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Fig. 1. Common carotid angiography, a) lateral and b) a.p. projection in the same dog. The contrast medium distribution is the same in both.

external carotid artery is markedly decreased, while the flow through the internal carotid artery is correspondingly increased. The administration of vasopressin prior to angiography thus results in an improved visibility of the vessels associated with the internal carotid artery.

This report presents a more detailed investigation of the vasopressin induced changes within the canine cephalic vasculature.

Material and Method. Seven mongrel dogs weighing 6.5 to 21 kg were studied by common carotid angiography before and after intravenous vasopressin administration.

The animals were fasted for eighteen hours before the radiographic examination which was performed under general anesthesia (25 mg per kg bodyweight nembutal Abbot) and endotracheal intubation. They were placed supine on a film changer. The skin was incised and a 0.8 mm o.d. needle was inserted into the common carotid artery and connected to a syringe by a polythene tube. Urografin 60 % (Schering) was injected manually in doses of 0.3 to 0.7 ml per kg bodyweight with saline perfusions between the injections.

Serial angiograms were obtained at a rate of two frames per second. Factors: 100 cm F.F.D., 80 kV, 100 mA, 0.003 to 0.006 seconds.

Angiography was performed prior to the administration of vasopressin as a control in all the dogs. A further angiographic examination was made later in three of the dogs to exclude the possibility that the medium itself was responsible for any changes in the angiograms.

Vasopressin (Postacton Ferring — chromatographically isolated vasopressin octapeptide) was given in doses of 0.5 to 1.5 IU per kg bodyweight diluted ten times in saline solution.



Fig 2 Common carotid angiography lateral projections a) Primary and b) repeat examination 10 min later No demonstrable differences in filling of the vessels nor any post angiographic vasodilation in (b)

injection time 5 minutes About five minutes after the injection repeat angiography was performed

The mean arterial blood pressure was measured with a mercury manometer connected to a catheter in the femoral artery

Comments on method used Common carotid angiography permitted a comparative estimation of the effect of vasopressin on the internal and external carotid vascular beds Rapid injection of the contrast medium into the common carotid artery favours complete mixture with blood hereafter referred to as contrast blood This rules out the possibility of a false selective flow of the medium to any part of the vascular system studied Further, different positioning of the head of the animals had no demonstrable influence on the distribution of the medium within the vascular area examined (Fig 1)

JEPPSSON & OLIN (1960) showed that filling of the cerebral vessels during common carotid angiography in rabbits was related to the injection rate and pressure Manual injection may result in variation in the rate and pressure of injection in different experimental animals However in the control angiographies performed no demonstrable differences in the filling of the cerebral

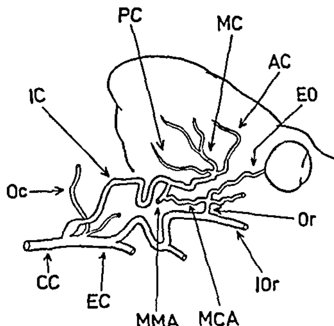


Fig. 3. Anatomic sketch of carotid artery in dog.

AC — anterior cerebral artery
CC — common carotid artery
EC — external carotid artery
EO — external ophthalmic artery
IC — internal carotid artery
IOr — infraorbital artery
MC — middle cerebral artery
MCA — maxillo carotid anastomotic artery
MMA — middle meningeal anastomotic artery
Oc — occipital artery
Or — orbital artery
PC — posterior cerebral artery

vessels or any post angiographic vasodilatation were observed (Fig. 2). Further, in the control angiographies, the different amounts of medium used had no demonstrable effect on its distribution within the vascular areas studied. Each dog was given the same amount of medium in the control angiography as in the angiography after vasopressin administration.

Anatomy of the carotid artery in the dog. The anatomy of the extra- and intra-cranial vessels in the dog was described by Ellenberger & Baum (1891) and Landeler (1899). Jewell (1952) and De la Torre et coll. (1959) added further information about the anastomoses between the internal and the external carotid arteries. The common carotid artery bifurcates some centimetres below the jaw.

The internal carotid artery has a bulbous enlargement just cranial to the carotid bifurcation but is otherwise narrower than the external carotid artery (Fig. 3). It enters the skull through the foramen lacerum posterius and the carotid canal, makes a ventral loop, and enters the cranial cavity through the carotid foramen. It passes through the cavernous sinus and traverses the dura at the level of the posterior clinoid process of the sella turcica; it then gives off the posterior hypophyseal artery, bends forwards and laterally, and finally joins the circle of Willis.

The external carotid artery gives off two branches: the ascending pharyngeal artery and, just beyond the bifurcation, the occipital artery (Fig. 3). It then supplies branches to the face and becomes the internal maxillary artery. The maxillary artery gives off the middle meningeal artery and, after passing through the alar canal, the orbital artery, and finally terminates in the pterygopalatine fossa as the infraorbital artery.

The orbital artery is short and subdivides into three branches: the maxillo carotid anastomotic artery (De la Torre), the external ophthalmic artery, and the external ethmoidal

Table

Summary of results obtained in 7 dogs subjected to common carotid angiography before (A) and after (B) vasopressin administration. The values given correspond to millimetres. 0 indicates no filling of vessel, + filling of vessel and — that no observation was made

Dog number	Carotid artery						Cerebral arteries					
	Common		Internal		External		Anterior		Medial		Posterior	
	A	B	A	B	A	B	A	B	A	B	A	B
1	3 5	4	0	2	3	4	+	+	+	+	0	+
2	3	4	0	1	3	3	+	+	+	+	0	+
3	3	3	1	1 5	3	2	+	+	+	+	0	+
4	3 5	4 5	0	2	3	3 5	+	+	+	+	0	+
5	—	4 5	—	2	—	3	—	+	—	+	—	+
6	2	2,5	0 5	1 5	2	2	+	+	+	+	0	+
7	4	4	1	2	3	3	+	+	+	+	0	+

artery. The maxillo-carotid anastomotic artery bends backwards after receiving a branch from the middle meningeal artery and joins the internal carotid artery where this passes through the cavernous sinus. The anastomotic artery of TANDLER (1899) is thus formed between the external and the internal carotid arteries (Fig. 3).

The two other branches of the orbital artery, the external ophthalmic artery and the external ethmoidal artery, form anastomoses with the internal ophthalmic and internal ethmoidal arteries respectively.

Condition of the animals. The animals tolerated the intravenously administered anesthetic and vasopressin well. They showed a reproducible response to vasopressin with an initial hyperpnea followed by a transient decrease in the respiratory rate. A few ventricular premature contractions followed by bradycardia were frequently observed; a transient increase of systemic blood pressure was also recorded.

Results

Angiographic findings before vasopressin administration. The contrast medium injection into the common carotid artery resulted in good demonstration of the external carotid artery and its branches (the occipital, ascending pharyngeal, mandibular, lingual, maxillary and temporal arteries and their tributaries). Filling was also obtained of the orbital artery and its branches (the external ophthalmic artery, the external ethmoidal artery and the maxillo carotid anastomotic artery) (Fig. 4a). The lamina vasculosa of the choroid of the eye

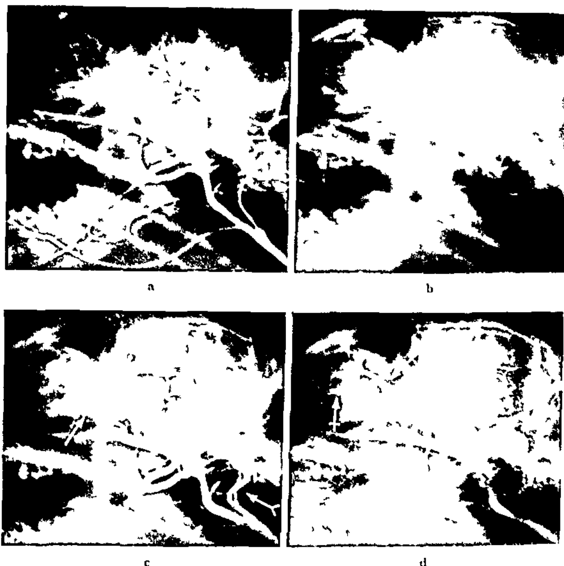


Fig. 4. Common carotid angiography. a) and b) Before vasopressin, c) and d) after vasopressin. No filling of the cervical trunk of the internal carotid artery in (a). Marked dilation of the external ophthalmic artery (→) and filling of the cervical trunk of the internal carotid artery (→) in (c). The chorioidea (+→) and ophthalmic veins (↔) are seen in (d).

was identified in the capillary filling phase as a faint accumulation of contrast medium (Fig. 4b).

The bulbous enlargement of the internal carotid artery was demonstrated in all the dogs examined. However, in 4 of the 7 dogs (see Table), the cervical trunk of the internal carotid artery could not be seen; in 3 dogs it was represented by a tiny vessel not exceeding 1 mm in diameter.

The intracranial division of the internal carotid artery and the anterior and middle cerebral arteries were demonstrated by contrast filling from the



Fig 5 Common carotid angiographic serial examination under the action of vasopressin a) Early in the examination Contrast medium filling only of the internal carotid and cerebral arteries b) Later in the examination Filling of the maxillo carotid anastomotic artery

external carotid artery via the maxillo carotid anastomotic artery (Fig 4a) The posterior cerebral artery could not be seen in any one of the dogs examined Slight filling of the intracranial and ophthalmic veins was evident during the venous phase (Fig 4b)

Angiographic findings after vasopressin administration The common carotid artery the external carotid artery the maxillary artery and the orbital artery were well filled and moderately dilated (Fig 4c) Compared with the controls the external ophthalmic artery was markedly dilated and in the capillary phase the lamina vasculosa of the choroid displayed a distinct accumulation of contrast medium (Fig 4d)

The contrast medium distribution to the remaining branches of the external carotid vascular system was markedly reduced Thus only a small amount of medium passed peripherally into the ramifications of the occipital artery the ascending pharyngeal artery and the arteries of the skull and jaw (Fig 4c) The cervical trunk of the internal carotid artery was well outlined and was markedly dilated in all the dogs examined (see Fig 4c and Table)

The circle of Willis and all the main cerebral vessels including the posterior cerebral artery were outlined by medium passing through the cervical trunk of the internal carotid artery The maxillo-carotid anastomotic artery was filled later than the internal carotid artery and its intracerebral branches

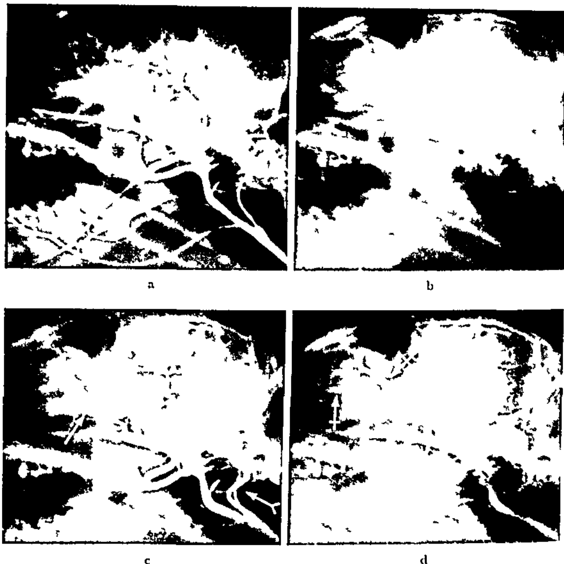


Fig. 1. Common carotid angiography. a) and b) Before vasopressin; c) and d) after vasopressin. No filling of the cervical trunk of the internal carotid artery in (a). Marked dilation of the external ophthalmic artery (→) and filling of the cervical trunk of the internal carotid artery (↦) in (c). The chorioidea (↔) and ophthalmic veins (↦→) are seen in (d).

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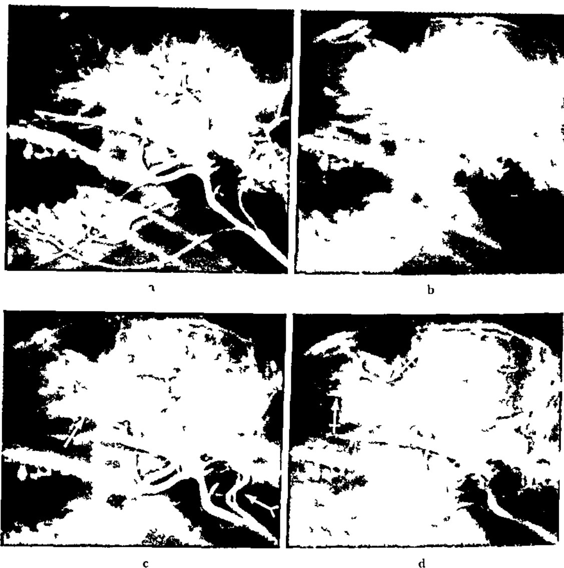


Fig 4 Common carotid angiography a) and b) Before vasopressin c) and d) after vasopressin *No filling of the cervical trunk of the internal carotid artery in (a) Marked dilation of the external* ophthalmic artery (→) and filling of the cervical trunk of the internal carotid artery (›→) in (c) The chorioidea (→→) and ophthalmic veins (↦→) are seen in (d)

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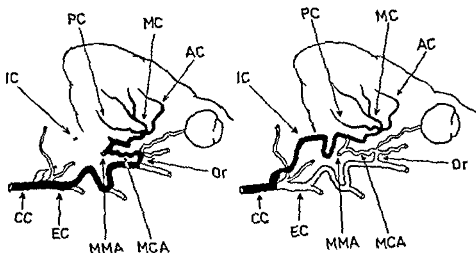


Fig 6 Schematic drawing to demonstrate the cerebral contrast blood flow before (left) and after (right) vasopressin administration

carotid vascular area The present investigation thus confirms earlier preliminary observations

The distribution of contrast blood within the vascular bed of the common carotid artery is determined by the vascular resistance within its different components A decreased contrast blood distribution to the extra cerebral area except to the eye after vasopressin administration could be explained by an increased vascular resistance within this area This is in agreement with the known vasoconstrictor effect of vasopressin The increased contrast blood distribution to the internal carotid artery to its tributaries and to the external ophthalmic artery and the eye could not be explained by any previously known vascular effect of vasopressin The increased contrast medium distribution to the internal carotid artery and the external ophthalmic artery suggests that vasopressin affects the vascular resistance in these vascular areas in a different manner than seen in the external vascular bed The vascular resistance within the distribution of the internal carotid artery and the external ophthalmic artery may be decreased remain unchanged or be increased However, if increased this increase must be of a minor degree when compared to the increase in vascular resistance within the external carotid vascular area

This selective effect of vasopressin on the contrast medium distribution within the carotid vascular system caused by changes in vascular resistance may reflect one or more of the following factors (1) a larger or a smaller smooth muscle mass in different vascular areas assuming that in each area

(Fig 5) Compared with the venous phase of the controls, the filling of the intracranial and ophthalmic veins was much more marked, and as a result the demonstration of these structures was greatly improved (see Fig 4d)

Discussion

The *constrictive effect of vasopressin on the contractile elements in blood* vessels is well documented (OLIVER & SCHAFER 1895, SOKOLOFF 1959, KONZETT 1960, SAWYER 1961 and BARRINGTON 1963) This effect on arterioles and capillaries results in an increased vascular resistance, with a subsequent decrease in blood flow through capillary beds and a rise in the systemic arterial blood pressure Until quite recently this was thought to be the sole effect of vasopressin on blood vessels, and was believed to occur uniformly throughout the entire vascular bed BERDE et coll (1961) reported an increased renal blood flow in cats and dogs after the administration of vasopressin They suggested that the increased renal blood flow may be secondary to redistribution of the circulating blood volume, caused by the vasoconstrictive effect of vasopressin on other vascular areas

BARER, in 1961, made the same observation of increased renal blood flow *in cats and rabbits after vasopressin administration,* and later (1963) showed that even small doses of vasopressin, without effect on systemic blood pressure, produced increased renal blood flow and diuresis BARER thought that the increased renal blood flow was due to a vasopressin induced renal vasodilatation

ARONSEN & NYLANDER (1964) using angiographic techniques, showed in a preliminary study that vasopressin in dogs caused a significant dilatation of large vessels, such as the aorta and pulmonary veins, and cardiac *dilatation* This was interpreted as a redistribution of the circulating blood volume from the arterioles and the capillary beds to larger vessels Further, vasopressin was also shown to have a selective action on the vascular beds of certain organs, provoking an increased 'contrast blood flow' through the brain, the eye, the liver and the kidney

The results obtained in the present study during common carotid arteriography before vasopressin administration indicate that the contrast medium distribution to the intra and extra cranial vascular areas was homogenous Thus, the distribution of the contrast medium to the branches of the common carotid artery was *related to their calibers*

The contrast medium distribution to the brain and the eye increased after vasopressin administration while it decreased to the other parts of the

one However, a definitive evaluation of this hypothesis must await studies of at least two additional factors the direct demonstration of changes in organ blood flow as distinct from increased contrast medium distribution, and the development of techniques suitable for plasma vasopressin measurements under physiologic conditions, one of these is at present under investigation

Angiographic studies performed in conjunction with pharmacologic agents that alter contrast medium blood flow distribution have not been extensively reported The present study strongly suggests that such techniques will prove useful in diagnostic radiology by providing a new means for the enhanced demonstration of selected organs and structures While no a priori analogy between dog and man can be made with respect to the effects of vasopressin preliminary observations in the latter reveal changes similar to those described in the present study in dogs It is therefore possible that the demonstration of organs during cerebral aortic and renal angiography in man may eventually be improved when performed with vasopressin In this context it should be noted that the studies of the present authors to date have been limited to chromatographically isolated Lysine vasopressin A variety of synthetic vasopressins with amino acid substitutions are now available It is by *no means certain that their effects* if any on blood contrast distribution will prove *similar* to those reported in this communication

Acknowledgement

The gift of Lostacton — chromatographically isolated vasopressin octapeptide — *from* the Ferring company Malmo is gratefully acknowledged

SUMMARY

Common carotid angiography was *performed* in 7 mongrel dogs before and after vasopressin administration Vasopressin appears to have a *selective* action on the cephalic vasculature as judged by angiographic techniques These *vascular changes* are described in detail and the possible implications of the findings in *terms of* both diagnostic radiology and the physiologic role of vasopressin are discussed

ZUSAMMENFASSUNG

Angiographie der Arteria carotis communis wurde an 7 mischrassigen Hunden vor und nach der Verabreichung von Vasopressin vorgenommen Vasopressin scheint *eine spezifische* Wirkung auf das *Hirngefäss-System* zu besitzen wie die Angiographie zeigt Die Wirkungen werden im Detail *beschrieben und die* Schlussfolgerungen soweit sie die diagnostische Röntgenologie und die physiologische Wirkung des Vasopressin betreffen werden erörtert

the muscle response to vasopressin is the same, (2) stronger or weaker vaso*constrictor response to* vasopressin in different vascular areas, (3) a vasopressin induced neural or hormonal compensatory mechanism resulting in vasodilatation in the brain and in the eye.

The results obtained also show that the contrast blood flow to the brain travels by different routes before and after the administration of vasopressin (Fig. 6). *It is therefore clear that in common carotid angiography before the* administration of vasopressin the cerebral contrast blood flow passes mainly through the external carotid artery via the anastomotic artery of Tandler — the middle meningeal anastomotic artery and the maxillo carotid anastomotic artery (DE LA TORRE) (Fig. 6a). The cervical trunk of the internal carotid artery was represented only as a tiny vessel in three of the dogs examined and was not present at all in the remainder of the dogs. The intracranial division of the internal carotid artery was well demonstrated in all the dogs examined. However, after the administration of vasopressin, the cervical trunk of the internal carotid artery became markedly dilated in all the dogs examined. Furthermore, in the serial angiograms the anastomotic arteries were filled later than the cerebral vessels. These observations together indicate that after vasopressin the contrast blood flow to the brain no longer passes through the *anastomotic arteries. The cervical trunk of the internal carotid artery* is under the action of vasopressin the major pathway for the cerebral contrast blood supply (Fig. 6b).

The visibility of the posterior cerebral artery after the administration of vasopressin could be explained by the increased total amount of contrast medium distributed to the cerebral vascular area, or possibly due to a decrease in flow from the basilar artery. The method used gives however no information about the blood flow in the basilar artery, and this latter factor can therefore *not be evaluated. The vasodilatation observed within the internal* carotid vasculature and the filling of part of the external carotid artery and the external ophthalmic artery may be explained by a displacement of the circulating blood volume from the arterioles and capillary beds to larger vessels, coincident with the measured increase in the arterial blood pressure.

The selective changes in the contrast medium distribution reported in this study, together with the authors' earlier observations, suggest the possibility of a hitherto unexplored physiologic role for vasopressin. Thus, the distribu*tion of contrast medium after vasopressin administration strongly favors* certain organs: the brain, eye, liver, and kidney, while distribution to other organs concomitantly is distinctly diminished. Although these observations were made with exogenous vasopressin, the hypothesis that a similar physiologic effect may occur in response to an endogenous hormone appears a reasonable

FROM THE DEPARTMENT OF THORACIC RADIOLOGY (DIRECTOR BJORN NORDENSTROM) KAROLINSKA SJUKHUSET STOCKHOLM, SWEDEN

PERCUTANEOUS BALLOON OCCLUSION OF THE AORTA

by

BJORN NORDENSTROM

The possibilities at ordinary thoracic aortography, with free flow in the aorta of obtaining satisfactory filling of small vessels arising from the aorta are restricted Injections above an occlusion of the aorta were made in experiments in animals and reported by the present writer in 1954 and in man 1955 in order to improve the examination conditions The risk of damage to the spinal cord apparent in the experiments in animals with the contrast media then available contra indicated any further investigations of this type in man A systematic series of investigations of the toxicity of new contrast media made it possible to continue the examinations in human subjects later with injection above the occlusion Parallel with these investigations the catheterization technique was being further developed In the first examinations with balloon occlusion of the aorta a double lumen catheter provided with a balloon was introduced into the descending aorta after exposure of the radial artery The balloon was filled through one lumen and the contrast medium injection was made through the other Certain difficulties were however encountered in introducing the relatively large catheter with the balloon into the radial artery

Submitted for publication 29 May 1964

RÉSUMÉ

Les auteurs ont fait sur 7 chiens des angiographies de la carotide primitive avant et après administration de vasopressine Les techniques angiographiques montrent que la vasopressine a une action sélective sur les vaisseaux céphaliques dont les modifications sont décrites en détail Ils examinent les conséquences possibles pour le diagnostic radiologique et pour le role physiologique de la vasopressine

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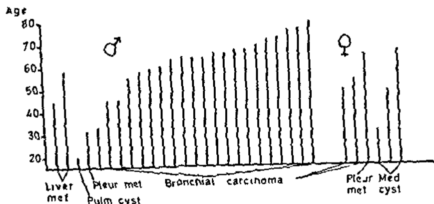


Fig 2 Age and sex distribution of the 31 patients examined and the diagnoses

The results of 30 aortographies of patients with percutaneous balloon occlusion of the thoracic aorta and two of the abdominal aorta are reported in this communication

Material The distribution of age and sex as well as the different conditions for which the investigations were performed are surveyed in Fig 2 Most of the thirty investigations were carried out in men, between the ages of 55 and 75 years with bronchial carcinoma Practically all of these had advanced, inoperable tumours

Technical considerations The percutaneous catheterization technique with balloon catheters via the femoral artery has not been connected with any marked difficulties The catheters are now roentgen opaque and this facilitates the procedure The pressure exerted by the blood stream on the upper part of the instrument entails a tendency for the balloon to be displaced distally in the aorta before it has made contact with the aortic wall The inflation of the balloon must therefore be carried out with the latter about 10 cm or more above the point where occlusion of the aorta is planned due consideration being given to the fact that the balloon may sometimes displace the injection catheter from its initial position

The aorta is occluded by the balloon with the injection catheter correctly placed beside it and with the tip close to the left subclavian artery (Fig 1a)



Fig 1 The percutaneously introduced balloon catheter is supported in the aorta with a stiff metal mandrin the walls of the former are flattened against the aortic wall by the pressure A percutaneously introduced catheter with its tip distal to the origin of the left subclavian artery lies in position for the injection Part of the contrast medium flows past the balloon to the abdominal aorta The right bronchial artery 3 mm in width is partly concealed by the aorta

A new technique for the percutaneous introduction of balloon catheters was therefore elaborated (NORDENSTROM 1962) The catheters were introduced percutaneously from the femoral artery to the aorta and the balloon kept in place, despite the pressure of the blood stream, by means of a special mandrin of silver steel (see Fig 1) The injection was made through a separate and also percutaneously introduced catheter placed with the tip above the occluding balloon The details of this catheterization technique and the construction of the instruments have been described (NORDENSTROM 1965) No more than 1 ml/kg bodyweight Urografin 60 % should be injected into the thoracic aorta above a temporary balloon occlusion



Fig 4 Squamous cell carcinoma of the right upper lobe The bronchial artery is very thin and medially displaced somewhat backwards no pathologic vessels in the tumour region.

tion with the occlusion and some declared that they experienced a heavy feeling in the lower part of the abdomen All the patients have referred to brief intense pain and a sensation of heat, especially in the back

Results

Bronchial arteries were identified in 15 of the 21 cases of bronchogenic carcinoma in men while no bronchial arteries were observed in the remaining 6 cases Of the two women with this condition the bronchial artery to the region was evident in one but not in the other

A winding bronchial artery about 3 mm in width arising from the arch of the aorta in a 54 year-old man with squamous cell carcinoma of the right upper pulmonary lobe formed a richly ramifying network of vessels suggesting an accumulation of contrast medium in the tumour (Fig 3a) The tumour region before the injection of contrast medium is depicted in Fig 3b

The bronchial artery was rather slender in another case of squamous cell carcinoma (Fig 4) The patient was a 64 year old man

The central part of the bronchial artery was widened in a few cases and the peripheral ramifications were not filled This is illustrated in Fig 5 in which a rather wide and winding bronchial artery runs to a lymph node in the left hilum some small branches of the bronchial artery deviate markedly The main trunk of the bronchial artery is however completely obstructed, this proved to be a case of a low differentiated squamous cell carcinoma

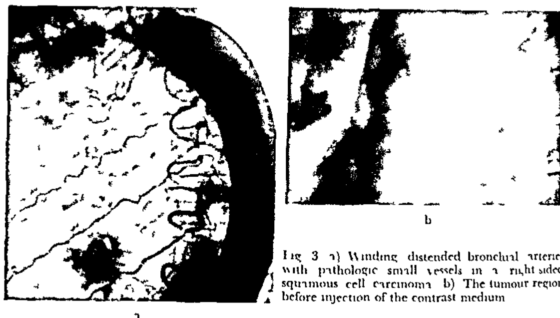


Fig. 3. a) Winding distended bronchial arteries with pathologic small vessels in a right-sided squamous cell carcinoma. b) The tumour region before injection of the contrast medium.

The inflation of the balloon in this case had been begun with the latter in the vicinity of the left subclavian artery, the tip of the injection catheter having been placed within the upper part of the ascending aorta. It is possible to occlude the aorta and place the injection catheter in the desired position by suitable manipulation of the balloon catheter with the steel mandrin. The contrast medium, when injected in the vicinity of the subclavian artery during occlusion of the aorta, passes mainly downwards into the aorta although some small aortic branches, chiefly intercostal arteries, are also filled. The medium may by-pass the balloon chiefly via anastomoses between the intercostal arteries to the distal part of the aorta. No untoward sequelae were observed following a single injection of 1 ml/kg bodyweight Urografin 60 % into the thoracic aorta.

The abdominal aorta in only 2 cases was occluded below the point at which the coeliac and renal arteries arise and 0.5 ml/kg bodyweight Urografin 60 % were injected. No complications, either by the occlusion or the injection, were met with.

Reactions. No serious symptoms due to the occlusion of the thoracic or abdominal aorta were encountered. The patients have stated that they felt a thudding sensation in the upper part of the body and head, in direct connec



Fig 6 Right medial mediastinal thin walled bronchial cyst with some of the distended bronchial arteries laterally displaced No pathologic tumour vessel

Complications The complications observed in connection with these investigations have included knotting of a catheter in one case A non opaque balloon catheter was being used and its progress during the catheterization could therefore not be observed As a result of the aortic pressure during the inflation the balloon turned completely round in the aorta the kinked tip of the catheter was drawn into a loop and an attempt to withdraw the catheter drew the loop into a firm knot It was found possible to coax the catheter out of the vessel which as a precautionary measure was then explored and sutured There were no further complications in this case

Local hematomas developed in two cases at the site of the introduction of the catheters in the groin As the hole for the introduction of a balloon catheter into the artery must necessarily be somewhat larger than that for the simple catheters a more careful and protracted compression of the site of puncture



Fig. [illegible] Squamous cell carcinoma with distended and winding bronchial artery running to a formation resembling a lymph gland in the left hilum where it seems abruptly to narrow; some of its smaller vessels appear detached, probably through compression by a lymph node or invasion

Diagnosis of benign conditions during temporary occlusion of the thoracic aorta was rare. In Fig. 6, the bronchial artery and some of the mediastinal branches in a 54 year old woman with a mediastinal cyst are depicted. The right bronchial arteries are probably somewhat distended and displaced to the right, no pathologic vessels are evident in the wall of the cyst, however. At operation a thin walled cyst containing a thick, greenish yellow material was removed from the mediastinum by blunt dissection.

Fig. 7 shows a tumour in the anterosuperior and left part of the mediastinum in a woman of 30. Fig. 7a illustrates an early phase of an injection above an occluded aorta. Both the right and left common carotid and subclavian arteries had common trunks from the aorta. The considerably distended and winding left bronchial artery arises from the left subclavian artery. Later phases of the investigation (Fig. 7b) revealed this bronchial artery to send a branch to the right lung; it terminated in a large number of fine vessels in the mediastinum and bronchial walls. No pathologic vessels were observed in the tumour. The tumour was easily removed at operation and proved to be a thin walled cyst with grey green, viscous contents. Some aggregations of lymphocytes and small cyst formations filled with lymph were present in the cell poor fibrous wall. There was no evidence of atypical cells or malignancy. The tumour was classified as a congenital mediastinal cyst.

aorta may be obtained Careful attention must be given to the spinal cord which is particularly sensitive to contrast media The results of earlier experiments in animals previous experiences from examinations of human subjects and the present investigation in 30 patients appear to indicate that a good margin of safety may be secured if only one injection of contrast medium is given and not more than 1 ml/kg bodyweight Urografin 60 % is used The occlusion of the aorta can and should also be limited to a relatively short period of time The important technical and toxicologic factors involved have been treated in detail elsewhere (TORNELL 1963 NORDENSTROM & TORNELL 1966)

The complication of knotting of the catheter was probably entirely due to the fact that the catheter was non opaque only opaque catheters are now being used

The method seems to afford future possibilities of investigating the broncho mediastinal vessels the intercostal arteries and other small arterial branches arising from the aorta

SUMMARY

The injection of contrast medium above a temporarily occluded aorta in 30 patients by a method previously described by the author is discussed The appearances of the bronchial arteries in a patient with a pulmonary squamous cell carcinoma as well as in two patients with mediastinal cysts are described The procedure affords considerably increased possibilities of investigating small arteries arising from the aorta

ZUSAMMENFASSUNG

Die Injektion von Kontrastmittel oberhalb einer zeitweilig blockierten Aorta mit einer bereits beschriebenen Methode wird an Hand von 30 Fällen erörtert Das Röntgenbild der Bronchialarterien bei einem Fall von Plattenepithelkarzinom und bei zwei Fällen von Mediastinalzysten wird beschrieben Die Methode ermöglicht das Studium der kleineren von der Aorta entspringenden Arterien

RÉSUMÉ

L auteur étudie les résultats de l injection de moyen de contraste en amont d une obstruction temporaire de l aorte réalisée chez 30 malades suivant une technique décrite par lui Il décrit l aspect des artères bronchiques chez un malade atteint d épithélioma pavimenteux du poumon et chez deux malades ayant des kystes médiastinaux Cette technique augmente considérablement les possibilités d examen des petites artères qui partent de l aorte



Fig. 7. Congenital medial mediastinal cyst. a) Left subclavian and carotid arteries arise by common trunk from the aortic arch. Left bronchial artery arises from left subclavian artery and forms fine-meshed vascular network in mediastinum near tumour. b) In later phases a stout branch to the right lung at the level of the arch arises from the left bronchial artery.

is required after withdrawal of the former. Since this precaution has been practized, no hematomas worth mentioning have been observed, and no other local complications have arisen at the place where the catheters were introduced.

Rupture of the balloon catheter has not occurred in these investigations, though on two occasions leakage between the balloon and the catheter has occurred. This difficulty has been overcome by modifying the construction of the catheter and the method of affixing the balloon.

Discussion

The percutaneous technique elaborated for the temporary occlusion of the aorta may be applied in suitable cases without any serious risk. High concentrations of contrast medium in the small arterial branches arising from the

RÖNTGENINSTITUT CAYETANO HEREDIA UND RÖNTGENABTEILUNG HOSPITAL OBRERO LIMA PERU

RÖNTGENOLOGISCHE DARSTELLUNG PROXIMALER BILIODIGESTIVER FISTELN

Eine neue Methode

von

RUDOLF SCHMARSOW

Die biliodigestive Fistel ist eine abnormale Verbindung zwischen irgend einem Segment der Gallenwege und des Verdauungstraktes. Man klassifiziert sie in spontane (BEHREND u. CULLEN 1950) und chirurgische. Die Hauptursache in der Ätiologie ist die biliäre Lithiasis, die nach NOSKIN u. Mitarb. (1949) 90 % der Fälle umfasst. Danach kommen mit 6 % die perforierten Ulcera und die restlichen 4 % sind dem Cancer der Gallenblase und Gallenwege, Abszessen der Gallenwege, Zysten usw. zuzuschreiben. Bei den Steinerkrankungen besteht im Allgemeinen ein Verschluss der Gallenwege, worauf eine Infektion erfolgt, die häufig ein Gallenblasenempyem oder eine Cholangitis zur Folge hat. Als weitere Entwicklung des Prozesses entsteht eine Pericholezystitis oder eine Pericholedochitis adhaesiva mit den in der Nachbarschaft liegenden Anteilen des Verdauungstraktes: Duodenum, Colon und Magen, der Häufigkeit nach angeordnet.

Vorläufige Mitteilung auf der Isten Peruanischen Radiologentagung in Trujillo, Dezember 1960. Vorgebracht auf dem X. Internationalen Kongress für Radiologie, Montreal, Canada, August—September 1962. Bei der Redaktion am 10. Februar 1964 eingegangen.

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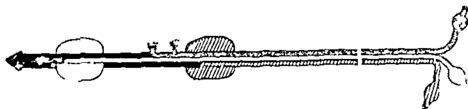


Abb 2 Schema der Dreiweg Doppelballonsonde

Die bevorzugte Lokalisation der Fisteln ist am Fundus der Gallenblase wegen seiner grosseren Beweglichkeit bedingt und ist dadurch befahigter mit den benachbarten Organen in Beruhrung zu kommen Beim weiblichen Geschlecht sind diese Fisteln 3 bis 5 Mal haufiger als beim Mann vor allen Dingen im sechsten und siebenten Lebensjahrzehnte

Die Symptomatologie stimmt allgemein uberein mit der Vorgeschichte einer Cholezystitis calculosa Das Auffällige in diesen Fallen ist vielfach das plotzliche Verschwinden der Beschwerden nach einem Hohepunkt von Gallenblasenkoliken was wohl auf eine Entleerung des Steines in den Darm hinweist PELSTOW (1942) erwahnt dass in der Mehrzahl seiner Falle sich die Symptome fortschreitend nach der Bildung der Fistel steigerten und die Koliken wurden intensiver, begleitet von Schuttelfrost und hohem Fieber Viele dieser Patienten befanden sich in einem sehr schlechten Ernahrungszustand Das mag moglicherweise durch eine Hepatitis und Cholangitis bedingt sein die sich durch Ruckfluss des Intestinalinhaltes entwickelte Haufig zeigten sich ausser der biliaren Symptome auch der Symptomenkomplex eines Duodenalulcus, der sich bis zum Bild einer Pylorus bzw Duodenalstenose erweiterte (Gallensteinileus) Gastrointestinale Haemorrhagien sind selten Durch die so unterschiedlichen Symptome die diese Erkrankten aufweisen wird die klinische Diagnostik sehr erschwert Zwei praktisch sichere diagnostische Zeichen sind (1) Gallensteinileus und (2) die Ausscheidung der Steine durch den Stuhlgang oder durch Erbrechen

Radiologische Diagnostik

HUNT u HERBST haben als erste 1915 praoperativ rontgenologisch eine biliodigestive Fistel dargestellt und zwar durch die Einnahme einer Barium suspension BORMAN u RIGLER konnten in der Literatur bis 1937 nur 83 Falle finden die praoperativ durch Rontgenuntersuchung diagnostiziert wurden PELSTOW erwahnt 16 Patienten mit praoperativ diagnostizierten Fisteln bei

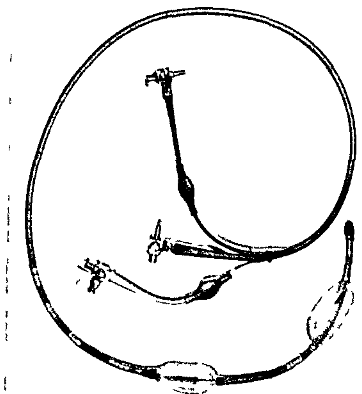


Abb. 1. Dreiweg-Doppelballon-Duodenalsonde: modifizierte Sengstaken'sche Sonde

BLÜHREND hat eine aussergewöhnlich seltene Verbindung zwischen der Gallenblase und dem Choledochus beschrieben. Die Fisteln bilden sich durch den Druck des Gallensteins, der dadurch ein Gangrän in der Mucosa in der Adhärenzenzone hervorruft, die sich zur Nekrose weiterentwickelt und so die Verbindung herstellt. Die grossen Steine können eine Nekrose durch Kompressionsischämie auslösen und in vielen Fällen entweichen diese Steine durch die Fistel und können einen Ileus durch Occlusion des Dünndarms herbeiführen.

Die spontanen biliodigestiven Fisteln sind verhältnismässig selten. BORMAN u. RIGLER (1937), die die entsprechende Literatur bis 1937 durchgesehen haben, fanden 67 Fälle mit inneren Gallenfisteln in einer Serie von 30 000 Obduktionen. ROTH konnte 43 bei 10 866 Kadavern feststellen. MIRIZZI (1946, 1960) wies mit Hilfe der operatorischen Cholangiographie 46 Fisteln bei annähernd 1 000 Operationen der Gallenwege nach. PEUSTOW (1942) gibt 3,5 % an. HICKEN u. COPAY kamen zu folgender Zusammenstellung: Vesicoduodenalfisteln 69 %, Vesicocolonische Fisteln 26 %, Vesicogastrische Fisteln 4,4 %. In Peru legten ROCHA (1956), mit 11 Fällen, und PAYET (1950), mit einem Fall, Arbeiten über dieses Thema vor.



Abb 4 Cholangographie mit der Sonde Kontrastfullung der Gallenwege durch die Fistel zwischen den Bulbus duodeni und dem Choledochus Gallenstein im unteren Ende des Choledochus kl in r Duodenald vertikel

Neue Methode zur radiologischen Diagnose der hohen biliodigestiven Fisteln durch eine Dreiweg Doppelballon Duodenalsonde

Beschreibung Fur einige Falle bestehen wesentliche Schwierigkeiten in der Darstellung der Gallenwege mit den bisher bekannten radiologischen Methoden insbesondere fur die Diagnose einer Oddiinsuffizienz oder einer hohen biliodigestiven Fistel und *deren exakte* Lokalisation Der Verfasser hat deshalb die folgende Methode ausgearbeitet

Das Verfahren besteht in der Isolierung *eines* Duodenalsegments durch eine Dreiwegesonde mit zwei aufblasbaren Ballons und man fullt das isolierte Duodenalsegment mit einem *Kontrastmittel* (verdunntes Biligrafin) durch den Weg der Sonde der zwischen den *Ballons* mundet Letzteres ermoglicht in diesem Duodenalabschnitt eine Fullung der *eventuellen Fistel* oder retrograde Kontrastfullung des Choledochus falls eine Oddiinsuffizienz besteht Bei nor

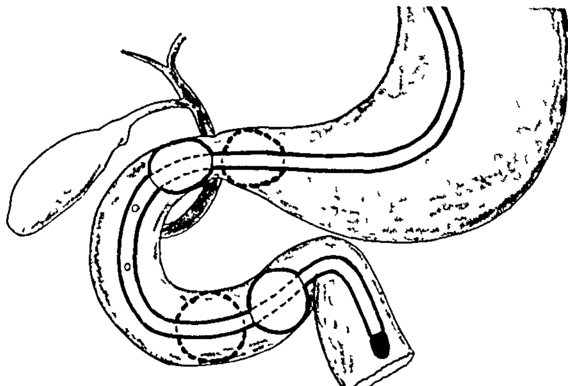


Abb. 3. Die hauptsächlichsten Positionsmöglichkeiten der Sondenballons

500 Operierten. Die radiologischen Zeichen der biliodigestiven Fisteln werden meistens in direkte und indirekte eingeteilt.

Direkte Zeichen:

1. Vorhandensein von Gasen in den Gallenwegen,
2. Eindringen von Bariumbrei in die Gallenblase und die zuführenden Gallenwege,
3. Deformation des Schleimhautreliefs des Gastrointestinaltraktes in der Zone der Einmündung der Fistel.

Indirekte Zeichen:

1. Cholezystographie und Cholegraphie sind pathologisch.
2. Feststellung von Steinen im Gastrointestinaltrakt.

Für den Fall, dass Luft in den Gallenwegen oder Reflux des Bariumbreies gefunden wird, muss man mit der Möglichkeit einer Oddiinsuffizienz rechnen, was aber doch recht selten ist. BOKMAN u. RIEGLER konnten vor 1931 nur 16 Fälle zusammenbringen. Falls dieser Reflux vorhanden ist, so kann er durch folgende Ursachen bedingt sein: (1) Zerstörung der Papille durch Erosion eines Steines, (2) durch zu langes Verbleiben eines Kurzdrains im unteren Choledochusanteil, das bis in das Duodenum reicht, (3) durch Neoplasie und andere Erkrankungsformen des Oddi (BOCKUS 1951).



Abb 6 Cholangiographie mit der Sonde Kontrastfüllung der Fistel zwischen dem Bulbus duodeni und dem Ductus cysticus oder der atrophischen Gallenblase Gallensteine im unteren Ende des Choledochus

Technik Die Sonde wird nach ungefähr vierstündigem Nüchternsein eingeführt und falls der Patient sehr empfindlich ist nach einem Anästhesiespray der Mundrachenhöhle mit einer 2 %igen Pantocainlösung Der distale Ballon wird unter radioskopischer Kontrolle im Bulbus oder zweiten Teil des Zwölffingerdarms dirigiert und vorsichtig aufgeblasen Wenn die Metallolive der Sonde den distalen Teil des Duodenums erreicht hat bläst man den proximalen Ballon in der gleichen Weise auf und zieht die Sonde *zurück* bis der zuletzt erwähnte Ballon im Bulbus duodeni zu liegen kommt Dann bläst man beide Ballons etwas mehr auf ohne dass Schmerz oder Übelkeitsgefühl durch Duodenaldehnung hervorgerufen werden Danach werden beide Luftwege verschlossen und die Sonde ist so fixiert Dann werden ungefähr 40 ml verdünntes Biligrafin unter radioskopischer Kontrolle und mit mässigem Druck durch den Kontrastweg der Sonde *eingespritzt* Wenn man keine Kontrastfüllung der Gallenwege erzielt lässt man die Sonde *weitergleiten* oder man zieht sie etwas zurück so dass im letzten Falle der proximale Ballon im Magenantrum zu liegen kommt natürlich *nachdem man* kurz die Luft aus diesem Ballon abgelassen hatte (Abb 3) Die Aufnahmen werden ausgeführt sobald sich die Gallenwege gefüllt haben Danach lässt man die Luft aus den Ballons ab und entfernt die Sonde

In der Zeitspanne von 1960 bis jetzt haben wir unsere Methode bei neun Patienten mit gutem Erfolg anwenden können Die Vermutung einer *biliodi*

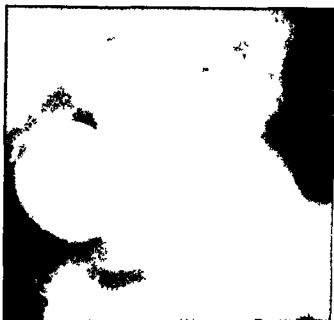


Abb 5 Bei der Magenuntersuchung mit Bariumbrei hat sich ein kleiner Teil des Einmündungssegments der duodenobiliären Fistel gefüllt Keine Kontrastfüllung im unteren Ende des Choledochus

malen Gallengangsverhältnissen haben wir das Verfahren gleichfalls versucht, ohne eine retrograde Kontrastfüllung zu erreichen, trotz Applikation starker Antispasmodica (Amylnitrit, Aether, Trinitrin) Wir gebrauchen das Biligrafin als Kontrastmittel wegen seiner Flüssigkeit und Unschädlichkeit im Magendarmtrakt, um Komplikationen einer akuten Jodintoxikation zu vermeiden

Die erwähnte Sonde (Abb 1) hat zwei Wege, die in je einem kleinen aufblasbaren Ballon enden Diese Ballons können Anfang und Ende des Zwölffingerdarms verschließen oder Pylorus und Duodenum Im Segment zwischen den beiden erwähnten Ballons endet der Weg für die Kontrastmitteleinspritzung Das Schema (Abb 2) gibt eine bessere Erklärung der Sondenstruktur Der Typ der Dreiweg Doppelballonsonde ist seit den Arbeiten von SENGSTAKEN u BLAKEMORE (1950) bekannt, die sie zur Blutungsstillung bei Oesophagusvarizen gebrauchten Wir haben jedoch die Sonde etwas modifiziert Im Jahre 1962 erfuhren wir dass BARTELHEIMER (1953) eine praktisch identische Sonde zur Pankreassaftgewinnung seit 1953 anwendet Andere sehr ähnliche Sonden werden seit 1954 bei der selektiven Bronchographie (STUTZ u VIETEN 1956) (Doppelblockierungskatheter von Maassen) und in der letzten Zeit bei der operativen Phlebographie der Leber nach HOLMES u Mitarb (1962) verwendet

Bei der Cholegraphie die weder Kontrastmittelfüllung der Gallenwege noch der Gallenblase zeigte war Luft in den Gallenwegen sichtbar

Bei der Untersuchung mit der Sonde konnte eine Fistel zwischen dem Bulbus duodeni und dem Ductus zysticus festgestellt werden Letzterer war ereitert gleichfalls der Hepato-choledochus mit einem Stein im unteren Ende (Abb 6) Bei dieser Möglichkeit wurde der proximale Ballon der Dreiweg Sonde in das Magenantrum gelegt dagegen der distale Ballon in die Pars caudalis des Duodenum Danach wurde ein Glas Bariumbrei eingenommen um eine Magenuntersuchung anzuschliessen Es konnte nur der Anfangsteil der Fistel dargestellt werden

Die Operation ergab die in den Radiographien dargestellte Fistel zwischen dem Bulbus duodeni und dem Collum der Gallenblase Ausserdem fand man den Stein am Ausgang des Choledochus Die sklerotische und atropische Gallenblase wurde extirpiert

Fall 3 Die Patientin war 26 Jahre alt Eine Cholezystotomie wurde 1957 ausgeführt bei der eine reichliche Anzahl von kleinen gelben Steinen entfernt wurden Einen Tag später traten erneut kolikenähnliche Schmerzen auf die 4 Tage anhielten Dabei hatte die Patientin leichtes Fieber Kopfschmerzen und schlechtes Allgemeinbefinden Am achten Tag post operativ trat wieder ein zart angedeuteter Ikterus auf der aber später wieder abklingte Es folgten dann zwei symptomfreie Jahre

Eine Cholezystektomie wurde in 1959 vorgenommen Bei der Operation fand man eine Stenose des Choledochus und ein Stein wurde aus dem Ductus entfernt Man legte dann eine Anastomose zwischen dem Cysticusstumpf und Duodenum an Die Patientin war nach der Operation für 5 bis 6 Monate beschwerdefrei Dann erschienen wieder die Symptome der Obstruktion der Gallenwege

Eine intravenöse Cholegraphie zeigte eine geringe Kontrastfüllung des Hepato-Choledochus mit zahlreichen Steinen Zum dritten Male wurde eine Operation ausgeführt und man legte nun eine Anastomose zwischen Duodenum und Ductus hepaticus an Steine wurden aus dem Choledochus und dem Cysticus entfernt Die Anastomose des Cysticus mit dem Duodenum wurde geschlossen

Einige Wochen nach der letzten Operation führten wir mit der Dreiweg Sonde eine Kontrollaufnahme der Fistel durch Der proximale Ballon lag im Antrum des Magens und der distale in der Pars caudalis des Duodenum Der Hepato-Choledochus und die intrahepatischen Verzweigungen stellten sich normal mit gleichmässiger Kontrastfüllung dar (Abb 7) Der Choledochus mündete in die Flexura duodeni cranialis ein Beim Examen für den Magen und Zwölffingerdarm mit Bariumbrei erhielten wir nur eine ungleichmässige Kontrastfüllung des Hepato-Choledochus und der intrahepatischen Verzweigungen unzureichend für eine Feststellung noch vorhandener Steine (Abb 8)

Danksagung

Der Autor möchte hiermit den Herrn Professoren Dr Oscar Soto Direktor des röntgenologischen Instituts Cayetano Hered a und Dr Enrique Gonzalez Vera Chef der röntgenologischen Abteilung Hospital Obrero seinen besten Dank aussprechen

ZUSAMMENFASSUNG

Die beschriebene radiologische Methode zeigt eindeutig den Sitz der hohen biliodigestiven Fisteln mit besseren Resultaten als die üblichen röntgendiagnostischen Verfahren und es



Abb. 7. Cholangiographie mit der Sonde schliesst die Möglichkeit von Gallensteinen aus und zeigt Durchlässigkeit der Choledochus-duodenalen Anastomose.

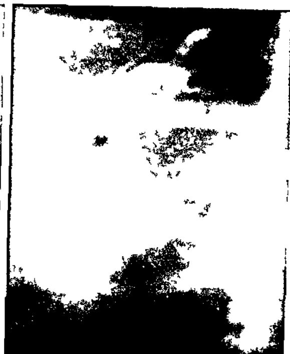


Abb. 8. Magenuntersuchung mit Bariumbrei zeigt unzureichende Kontrastfüllung der Gallenwege.

gestiven Fistel wurde durch Luft in den Gallenwegen mit den üblichen radiologischen Untersuchungen aufgestellt. In sämtlichen Fällen konnten die Fisteln genau dargestellt werden.

Kasuistik

Fall 1. Es handelte sich um eine Patientin von 67 Jahren, ohne Vorgeschichte einer Gallenoperation, mit einer biliodigestiven Fistel, die durch Luft in den Gallenwegen — auf den cholezystographischen Aufnahmen sichtbar — vermutet wurde. Keine Darstellung der Gallenwege konnte mittels der cholegraphischen Untersuchungsmethode erreicht werden. Die Dreiweg-Doppelballon-Sonde wurde unter radioskopischer Kontrolle im Duodenum hineingelegt, mit dem proximalen Ballon im Bulbus duodeni. Nach Einspritzung des Biligrafins füllten sich die Gallenwege vom Bulbus duodeni und die genaue Lage der Fistel konnte festgestellt werden (Abb. 4). In dem unteren Teil des Choledochus war ein Cholesterinstein sichtbar.

Fall 2. Es handelte sich um eine Patientin von 68 Jahren, die im November 1961 im Krankenhaus wegen einer Cholezystitis calculosa behandelt wurde. Im gleichen Jahr wurde sie wegen epiploischer und inter-intestinaler Verwachsungen operiert. Ausserdem wurden die Gallenblasensteine durch eine Cholezystotomie entfernt. Die Patientin erscheint im Oktober 1961 wiederum im Hospital mit Koliken im rechten Hypochondrium und Epigastrium, mit einem Ikterus und Kopfschmerzen.

FROM THE DEPARTMENTS OF ROENTGENOLOGY I AND PATHOLOGY SODERSJUKHUSET STOCKHOLM SWEDEN

EXTRACARDIAC ANASTOMOSES TO THE MYOCARDIUM

Preliminary report of angiocardiographic and anatomic studies

by

HAKAN ARVIDSSON and ANDERS MOBERG

Anastomoses between the systemic arteries and the coronary arteries have been known since the beginning of the nineteenth century The anatomist VON HALLER (1803) found that after injection into the coronary arteries arteries leaving the heart in the region of the great vessels communicated with the mediastinal vessels GROSS (1921) made injection studies in the same manner and also demonstrated extracardial anastomoses HUDSON MORITZ & WEARN (1932) injected India ink into the coronary arteries at a pressure of 220 mm Hg They concluded that extracoronary anastomoses increase in size and number with age but did not mention whether or not there was any association with the degree of coronary atheromatosis Summarizing they stated that "this rich potential extracardiac coronary collateral circulation is probably of significance in compensation for sclerosis of the large trunks of the coronary arteries KLINE et coll (1956) and VIDONE et coll (1956) published papers on the development of the bronchial collateral circulation including experimental studies in dogs Anastomoses of three types transpleural retrocardiac

Submitted for publication 27 February 1964

traten weder Komplikationen noch unangenehme Zwischenfälle bei der Durchführung ein. Die Methode bietet nicht mehr Schwierigkeiten oder Beschwerden für den Patienten als jede andere Untersuchung mit einer oralen Sonde.

SUMMARY

A method is described by means of which it is possible clearly to demonstrate the site of high biliary digestive tract fistulas in a more reliable manner than by already established diagnostic methods. No complications or other incidents were met with. The procedure is no more difficult or inconvenient for the patient than other methods of intubation.

RÉSUMÉ

Description d'une méthode permettant de préciser clairement le siège de fistules bilio-*digestives hautes plus sûrement que par les méthodes existantes. Elle n'a causé ni complica*tions ni incidents. Elle n'est pas plus difficile ni plus désagréable pour le malade que les autres méthodes de tubage.

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FROM THE DEPARTMENTS OF ROENTGENOLOGY I AND PATHOLOGY, SÖDERSJUKHUSET STOCKHOLM SWEDEN

EXTRACARDIAC ANASTOMOSES TO THE MYOCARDIUM

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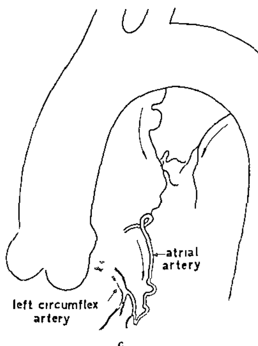
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Anastomoses between the systemic arteries and the coronary arteries have been known since the beginning of the nineteenth century. The anatomist VON HALLER (1803) found that after injection into the coronary arteries arteries leaving the heart in the region of the great vessels communicated with the mediastinal vessels. GROSS (1921) made injection studies in the same manner and also demonstrated extracardial anastomoses. HUDSON, MORITZ & WEARN (1932) injected India ink into the coronary arteries at a pressure of 220 mm Hg. They concluded that extracoronary anastomoses increase in size and number with age but did not mention whether or not there was any association with the degree of coronary atheromatosis. Summarizing they stated that "this rich potential extracardiac coronary collateral circulation is probably of significance in compensation for sclerosis of the large trunks of the coronary arteries". KLINE et coll. (1956) and VIDONE et coll. (1956) published papers on the development of the bronchial collateral circulation including experimental studies in dogs. Anastomoses of three types: transpleural, retrocardiac

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a

b



c

Fig 1 Coronary angiograms lateral projection in a 50 year old male with a history of several infarctions (previously reported by Di GUGLIELMO) a) Subtraction The left circumflex artery is filled from wide bronchial arteries via a wide left arterial artery b) The circumflex artery is totally occluded (arrow) c) Combined schematic diagram of (a) + (b) The bent arrows indicate the direction of flow

and intercoronary developed after cardiopneumonopexy A review of the coronary collateral circulation was published recently by BLOOR & LIEBOW (1965)

Despite this evidence, extracardiac anastomoses have received little attention among the numerous investigators of coronary pathology and angiography This may be due to the fact that the collateral vessels are small and difficult to observe even in good quality angiograms It is also impossible with cine radiography or selective coronary angiography (SONES 1959) to demonstrate the bronchial vessels

The first angiographic demonstration in vivo of extracardiac anastomoses to the coronary system was published by DI GUGLIELMO in 1960 This author described a patient with marked coronary atheromatosis and occlusion of the circumflex branch of the left coronary artery Wide and tortuous mediastinal vessels which had the appearance of bronchial vessels, were observed in a late phase of conventional coronary angiography The circumflex branch of the left coronary artery distal to an occlusion was filled with contrast medium via these vessels (Fig 1) The extracardiac coronary anastomoses in this patient were recently re examined thoracic aortography being performed with contrast injection into the descending aorta at the isthmus region e g close to the origin of the bronchial arteries No medium reached the ascending aorta during the examination Dilated bronchial arteries as well as a faint but conclusive filling of the distal part of the circumflex branch of the left coronary were demonstrated observations that stimulated further studies of the problem

Material and Methods

Angiography in living human subjects The number of coronary angiographies included in this preliminary report is limited, only 27 coronary angiographies in patients with varying degrees of atheromatosis The patients were examined because of infarction angina pectoris or high blood cholesterols Fifteen angiocardiographies from patients without known coronary artery disease were chosen as controls Aortography in the latter group was performed for various reasons aortic valvular stenosis and mitral stenosis as well as for chest pain suggesting coronary disease although no significant coronary changes were evident in the angiograms

The angiographies in the coronary group were carried out in the following way The catheter a PE 205 (thin walled grey Ödman Ledin) with an end loop with side holes (PAULIN 1964) was introduced into the aorta by the Seldinger technique the loop being placed immediately above the aortic valves with the aid of an image intensifier and a monitor screen Two injections were



Fig. 2. Coronary angiogram in a 56 year old male with a history of infarction and angina pectoris. Wide tortuous bronchial vessels are seen to pass down towards the left atrium. General atheromatosis of the coronary vessels but no total occlusion (not shown in the figure which is from a late film).

made with a pressure syringe (Gidlund), 50 to 70 ml Urografin 60 %, or in later examinations 60 to 75 ml Isopaque, being administered at each injection. The lateral and left anterior oblique projections were employed. The examinations were performed without general anaesthesia in maximum voluntary inspiration, the injection and roll film changer being started simultaneously after the patient had held his breath for 2 to 5 seconds. The exposure program consisted of 3 sec at 6 exposures/sec and 8 to 10 sec at 2 exposures/sec. The control material was examined according to the same general principles but only one injection was usually given. Anteroposterior and lateral films were exposed simultaneously.

The right and left anterior descending and circumflex coronary arteries were scrutinized for the degree of arterial calcification and stenosis. The observations

were classified from 0 signifying no atheromatosis to ++++ indicating total occlusion The bronchial arteries were studied carefully for visibility, size and possible connections with the coronary system

Angiography in autopsy material Angiographic studies in an autopsy material were carried out simultaneously in twelve cadavers by internal mammary artery injection and in 23 cadavers by bronchial artery injection The post mortem material was selected in a certain degree in that young subjects were excluded and attempts were made to obtain cases with a history of infarction or angina pectoris

The post mortem examination was started by exposure of the internal mammary arteries which were injected with microcrystalline barium sulphate suspension the chest organs were then removed en bloc Roentgenograms were obtained in different projections of the chest organs in toto and of the isolated heart with and without the pericardium

In the series of bronchial artery injections, the chest organs were taken out with great care and the descending aorta was opened from behind The bronchial arteries were identified and injected with microcrystalline barium contrast suspension roentgenograms being then obtained as previously described

The films were examined for the presence of contrast medium in the coronary arteries The extent of the contrast filling was observed i e whether medium was present in the atrial walls only or if vessels were also filled at the ventricular level In the latter case attempts were made to identify the afferent vessels

Results

Angiocardiography in living subjects The bronchial arteries were visible in only three patients of the control group one of whom had slight atheromatosis of the circumflex artery The widening of the bronchial arteries was not marked in any of the three and the vessels could not be followed to the region of the heart The bronchial arteries were visible in 15 of the 27 patients of the coronary group and in 8 of these the bronchial arteries could be followed down to the region of the left atrium even though direct proof of contrast passage into the heart could not be established (Fig 2) In these 15 patients the degree of atheromatosis in the circumflex branch was classified +++ or ++++ Furthermore only one patient, classified as +++ atheromatosis of the circumflex branch had no demonstrable bronchial arteries None of the patients with a minor degree of atheromatosis (0 or +) of the circumflex branch had visible bronchial arteries Proof of the existence of an extracardial vascular connection was only established in two patients — in the one described above and in another patient in whom refilling of the circumflex branch occurred late

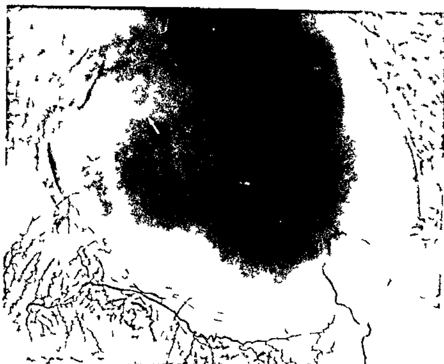


Fig. 3. Isolated chest organs from a patient with an anterior infarction post mortem internal mammary artery injection. The pericardial arterial filling is well demonstrated and there is a slight filling of the atrial vessels (arrow).

in the examination. No contrast medium was visible in the other coronary vessels at that time and the medium must therefore have originated from an extracardiac source.

The internal mammary arteries in the control group were small and without demonstrable branches to the pericardium except in one patient who also had small visible bronchial arteries. This patient had a minimum degree of atheromatosis in the interventricular branch of the left coronary artery. In the coronary group, enlargement of the mammary arteries with visible pericardial branches occurred in 9 patients, 6 of whom had a marked increase in pericardial branches and atheromatosis graded as + + + or + + + + of the right coronary artery or the anterior descending artery, or both. Among the patients without visible mammary artery ramifications to the pericardium, four had however + + + or + + + + of the right coronary artery and the anterior descending branch of the left coronary artery.

Studies in autopsy material. Arteries in the parietal pericardium were filled with contrast medium in all the subjects in whom the internal mammary arteries were injected. In only two of the 12 subjects were vessels demonstrated within



Fig 4 Heart (pericardium removed) post mortem bronchial artery injection. Two large afferent arteries are marked with arrows The loop of the sinus node artery is clearly visible (++) and from this artery the right coronary artery and through intercoronary anastomoses the left coronary artery have been filled There are numerous septal collateral branches

the heart (Fig 3), these were of very small calibre and located in the wall of the left atrium

In the bronchial injection studies, the contrast medium passed into vessels of the heart in 22 of the 23 subjects, in all of them, vessels within the atrial walls were filled and in 10 of the 22 vessels at the ventricular level as well The medium could be followed from the atrium most often via the sinus node artery (ramus ostii cavi superioris), down to one of the main coronary arteries at the ventricular level (Fig 4)

Discussion

The natural development of arterial anastomoses to occluded areas in peripheral parts of the circulation is well known especially in the leg where collateral circulation formation is common and may be studied by repeated

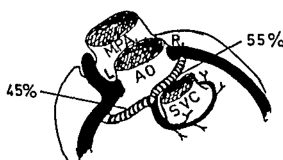


Fig. 5. Schematic drawing of posterosuperior aspect of the coronary arteries. L — left coronary artery. R — right coronary artery. MPA — main pulmonary artery. AO — aorta. SVC — superior vena cava. The two possible origins of the sinus node artery encircling the SVC are shaded.

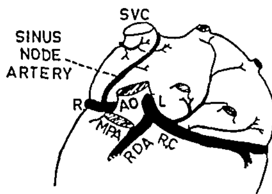


Fig. 6. Schematic drawing of the left lateral aspect of the atrial arteries. RC — circumflex branch of the left coronary artery. RDA — anterior descending branch of the left coronary artery. Other symbols as in fig. 5.

angiographies. The same is true also of the brain circulation. The development of collaterals to the heart has apparently received little attention. It is, however, reasonable to assume that the same laws are valid for the heart as for other parts of the circulatory system, i.e. when a sufficient pressure gradient between two adjacent vascular systems is present, collateral vessels develop or increase in size. It is known that the collaterals to an ischemic area develop from the nearest vascular bed. Except for a direct vascular supply from the left ventricle, two main arterial systems may function as collaterals to the coronary system, i.e. (1) the internal mammary arteries with their tributaries and (2) the bronchial arteries.

The internal mammary artery system is known to supply the anterior parietal pericardium through small pericardial branches. The bronchial arteries normally supply the posterior parts of the pericardium. When no pericardial adhesions exist the only possible pathway to the myocardium is through the pericardial reflexion located posteriorly to the heart between the aorta, the superior and inferior venae cavae and the pulmonary veins. This means that collaterals from the mammary system have to develop around the heart in the parietal pericardium — an area that normally has a relatively poor blood supply — to reach the crucial portal of entrance to the myocardium posteriorly. The bronchial arteries, on the other hand, pass more or less directly down to the area of the pericardial reflexion close to the left atrium. It might therefore reasonably be expected that these latter would be the closest and most efficient vessels for collateral development to the coronary arteries. The present study appears to support this assumption. In the angiographies performed in

living subjects as well as in the autopsy material there is definite evidence of a more efficient collateral formation through the bronchial arterial system than via the mammary arteries

The most suitable intracardiac pathway to the main coronary arteries for collateral connection would be through the largest atrial artery, the sinus node artery (ramus ostii cavi superioris) This may arise from the right or the left circumflex coronary artery but it reaches the region of the superior vena cava where it supplies the sinus node (Figs 5 and 6) This artery was also well filled with medium in several of the post mortem angiograms (Fig 4) Other possible but minor arteries for collateral circulations would be the anterior inter mediate or posterior atrial arteries arising from the right or the left circum flex coronary artery and ordinarily supplying areas up to the vein inlets If an occlusion is proximal to the origin of any of these arteries the prerequisites for collateral formation are present a pressure gradient and preformed small vessels

SUMMARY

It has been shown by this investigation in vivo as well as post mortem that anastomoses exist between the bronchial and the main coronary arteries Anastomoses between the internal mammary arteries and the coronary arteries seem to be very rare

ZUSAMMENFASSUNG

Es wurde bewiesen dass am Lebenden und am Kadaver Anastomosen zwischen den Bron chial und den Koronararterien bestehen Anastomosen zwischen der Art mammilaris interna und den Koronararterien mussen als selten angesehen werden

RESUMÉ

Ce travail de recherche a montré in vivo et post mortem qu il existe des anastomoses entre les arteres bronchiques et les principales artères coronaires Les anastomoses entre les arteres mammaires internes et les artères coronaires semblent très rares

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FROM THE ROENTGENDIAGNOSTIC DEPARTMENT (DIRECTOR PROF FOLKE KNUTSSON) UPSALA UNIVERSITY HOSPITAL, UPSALA SWEDEN

VERTEBRAL GENESIS OF IDIOPATHIC SCOLIOSIS IN CHILDREN

by

FOLKE KNUTSSON

Idiopathic scolioses have been thoroughly studied by a great number of clinical workers and include those scolioses which appear during the growing years and to which no direct cause can be assigned The condition may begin during the first three years of life or later The curvatures often increase to severe deformities but in some cases there is a spontaneous return to normal they appear most often in the lower part of the thoracic spine to be followed by compensatory or other kinds of curvatures Various stabilizing operations have tried to prevent progression but the results have often been unsuccessful Since the biologic cause of idiopathic scoliosis is unknown it is impossible to carry out adequate basic treatment

Whether the vertebral anomalies are the primary cause of the scoliosis or only the result of a secondary adaptation has been much discussed As this form of scoliosis appears during the period of growth, it has been naturally asked whether it is dependent on a disturbance of the normal growth of the spinal column This line of thought gave rise to experiments in growing animals The growth zones of the vertebra were injured in different ways and the effect on development studied MOSER has published a survey of the animal experiments performed In order rightly to estimate the results of this experimental research a complete knowledge of the normal vertebral growth and of the factors influencing on the development is needed

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The individual vertebra constitutes an element of the vertebral column, a structure possessing static and dynamic functions The vertebral bodies, built up into a pillar, bear the strain, the function of the arches being limited to create stability by restricting movement The development of the vertebra is consequently directed by biologic forces analogous to those determining the growth and conformation of the bones of the extremities The individual vertebra is also a unit in the structure of the spinal canal which serves as a container for the spinal cord with its nerves and membranes It therefore is natural that the development of the vertebra is also influenced by the growth of the cord

A vertebra consists both anatomically and biologically of two different parts a body and an arch

The vertebral body

Vertical growth The body is analogous to the bones of the extremities and increases in height continuously during the whole period of growth This growth takes place in the zone of ossification between the body and the cartilaginous plate MOSER in animal experiments found that growth is higher at the upper than at the lower surface and his histologic examinations of autopsy material from children revealed that the zone of ossification is higher at the upper than at the lower surface as well These results mean that the growth activity is greater at the upper than at the lower surface of the vertebra KNUTSSON, on the other hand, made an observation which indicates that the growth is taking place at the same rate at both surfaces In those cases in which the 'equator of Hanson can be observed in a mature vertebra, it always lies exactly in the middle of the lateral surfaces of the vertebral surfaces, this position indicates that growth has taken place uniformly at both surfaces

Ossification in normal cases takes place uniformly along the whole vertebral surface which thus remains completely flat and even throughout the period of growth Observations can be made which indicate that the growth is affected by mechanical pressure on the field of ossification (see legends to Figs 1 and 2) These suggest that the normal plane growth at the surface of the vertebral body is due to a uniform mechanical pressure on the whole surface If the pressure is reduced on a certain part of the surface, then the growth rate will be increased The pressure is thus important for the development and the finite form of the vertebral body

Horizontal growth There is an increase in the height as well as in the transversal and sagittal directions throughout childhood and adolescence as long as the individual is still growing The vertebral body thus grows in the same manner as the extremities



Fig 1 (above) Intraspongiosus disk herniation following SCHEUERMANN's disease at lower surface of L1 and upper surface of L3 This obviously caused a reduced resistance to the growth of the interposed vertebral body L2 and resulted in dome shaped swellings



Fig 2 (right) Idiopathic scoliosis The most advanced development of the ring epiphyses is at the edge of the vertebral body which is part of the convexity increased height of vertebral body corresponding area The scoliotic curvature doubtless causes decreased pressure on the vertebral surface within these areas the ring epiphyses are probably stretched

After the completion of endochondral ossification horizontal growth of the vertebral body takes place by means of periosteal apposition with the interesting feature that it is not equal all round the cylinder but takes place only at the front and sides (KNUTSSON) The author in a few cases has been able to trace the development of a vertebral body by utilizing an early intraspongious disk prolapse as the point of orientation It was observed that growth was taking place anteriorly but not posteriorly The absence of growth posteriorly towards the spinal canal with consequent non encroachment upon its lumen during the course of growth of the vertebral body was noted

The vertebral arch

The vertebral arch, on the other hand, is analogous to the cranium and grows at the same rate. The part of the arch which constitutes the spinal canal and surrounds the spinal medulla is thus analogous to the skull which surrounds the brain. As early as 1 to 2 years of age, both halves of the arch have become unified in bone. As a result of this, continued growth, leading to increase in size of the spinal canal, occurs exclusively at the neuro-central junction. This growth occurs rapidly during the first 3 to 5 years of life and then more slowly until 10 years of age, when it is complete. The ring of the arch has thus attained its final size by about 10 years of age.

There is a risk of conflict in this double development of a vertebra. According to the literature, growth at the neuro-central junction is complete between 3 and 8 years of age. This wide time limit may seem strange but may be explained if completion occurs at different ages in different parts of the vertebral column. No systematic anatomical study of the time of completion in different vertebrae has been carried out and a practical roentgenologic assessment is impossible.

Reproductions of autopsy material from vertebrae of children appear in the literature which permit examination of the neuro-central junction. The *joint was complete in C4, Th3 and L4 but incomplete in Th7 in a 7 1/2 year* old girl. The joint was complete in C1 and L4 but incomplete in Th3 and Th7 in a 3 1/2 year old girl (INGELMANN). The joint was incomplete in Th5 and L2 in a 3 year old boy and it was incomplete in Th5 and Th6 in a 4 year old boy. The joint was incomplete on one side in Th2, Th4, Th8 and Th10 but complete on both sides in Th11, L1 and L2 in a 6 1/2 year old girl with scoliosis (NICOLADONI) (as shown below).

Age in years	3	3 1/2	4	6 1/2	7 1/2
Th 2				Open	
3		Open			Closed
4				Open	
5	Open		Open		
6			Open		
7		Open			Open
8				Open	
9					
10				Open	
11				Closed	
12					
L 1				Closed	
2	Open			Closed	
3					
4		Closed			Closed
5					

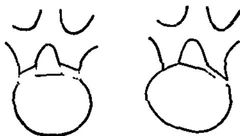


Fig 3 Diagram of the effect of unequal growth on the neuro-central junctions The vertebral body is rotated towards the side where premature synostosis occurs thus producing scoliotic curvature with the convexity towards this side

These few observations are in favour of completion occurring at different times in different parts of the vertebral column and furthermore of it occurring last in the thoracic spine The harmonious development of the vertebral column even up to 8 years of age, thus depends on the paired neuro central junctions growing absolutely similarly and being complete at the same time On the other hand if growth is not uniform, asymmetry between arch and vertebral body is to be expected

Growth conflict in paired neuro central junctions

The symmetric shape of the arch is completely dependent on growth at the neuro central junction after the age of 1 to 2 years If this takes place at a different rate and leads to a premature synostosis on one side the vertebral body is twisted out of its harmonious relationship with the vertebrae above and below Such a unilateral retardation in growth leads to the distance between the joint processes and body of the vertebra being continually shorter than on the opposite side during the time of growth The conditions required for normal development of the vertebral column are that growth at the neuro central junctions occurs at the same rate on both sides (Fig 3)

This problem has been dealt with by NICOLADONI who studied the neuro-central junction in a series of dead children with infantile scoliosis aged 1 6 6 1/2 and 7 years The neuro central junction was without exception completely open on the concave part of the scoliotic curvature and completely closed on its convex part or more open and more closed respectively Thus growth was more rapid on the concave side causing a prolongation of the peduncle which in its turn produced a rotation of the vertebral body towards the convex side

The 8th thoracic vertebra which was at the apex of the curvature convex to the right showed a completely synostosed neuro central junction on the convex side and a completely open junction on the concave side in one of NICOLADONI's cases (Fig 4) The vertebral body was rotated towards the convex side This change must be ascribed to a retarded and premature synostosis in the neuro central junction on the convex side



Fig. 4. Vertebra Th 8 in a 6 1/2 year old child with a scoliosis convex to the right. The neuro-central junction is completely open on the concavity of the curvature but fused with bone on the convex side; the vertebral body is rotated towards the latter. (From NICOLADONI's publication.)

SCHILDT came to the conclusion that the characteristic change in the scoliotic vertebra can be explained only by an injury to the neuro-central junction. He has suggested rickets as a possible cause.

It should be possible to explain the progress of the scoliosis with knowledge of the definitely complete growth of the arch at about 10 years of age, and the subsequently continuous growth in height of the vertebral body. After the vertebral body has rotated in a lateral direction and the displacement has been combined with lordosis and lateral deviation (SOMMERVILLE), the conditions of loading have changed. The effect on the growth of the mechanical pressure on the zone of ossification has been discussed above (Figs. 1 and 2). The pressure becomes greater on the posterior areas of the surfaces of the vertebral body than on the anterior areas. This means that the vertebral body grows more rapidly in height anteriorly than posteriorly and that the curvature increases continuously. Because of this there is reason to suppose that premature closure of the neuro-central junction on one side may initiate a scoliotic curvature.

OTTANDER carried out an interesting experiment. He injured mechanically the right neuro-central junction of L2 in a 28 day-old pig. When the animal was killed three months later, fusion had appeared and a slight scoliosis with the convexity to the right had developed.

The question may be posed if it can be plausibly explained why the differing growth in the paired neuro-central junctions appears particularly in the thoracic region. There is reason to believe that growth at the neuro-central junction in this part of the vertebral column continues longer than in any other part and that closure may even be delayed until 8 years of age (see page 398). This situation may provide a predisposing cause.

Conclusion

Idiopathic scoliosis consists of rotation lordosis and lateral deviation There is evidence that rotation can be elicited by varying rates of growth in the paired neuro central junctions (NICOLADONI) Growth in the neuro-central junction is complete at different times in different parts of the vertebral column between 3 and 8 years Some observations are in favour of its continuing longer in the thoracic region than in other parts of the vertebral column In discussing the origin of idiopathic scoliosis it may be asked whether retarded growth at one of the paired neurocentral junctions can initiate a scoliosis from the rotation of the vertebral body out of its harmonic relationship to the other vertebral bodies Rotation occurs towards the side in which growth in the neuro central junction is retarded and the scoliosis is convex on that side (NICOLADONI) There thus exists a theoretical possibility of inhibiting increasing rotation during the period of growth by an epiphysiodesis at the neuro central junction on the concave side of the curvature in order to be effective it must be carried out at an early stage It might be possible by such means to counter act increasing rotation, and so inhibit further increase in the curvature, which depends on continued growth in the height of the vertebral bodies Further research into this problem is required

SUMMARY

The cause of idiopathic scoliosis is still unknown although there is evidence of unequal growth at the paired neuro-central junctions which may lead to rotation of the vertebral body out of its relationship to the harmonic vertebral column The progress of the scoliosis which follows can be explained by the continued growth of the vertebral bodies

ZUSAMMENFASSUNG

Die Ursachen der idiopathischen Skoliose verbleiben unbekannt obwohl bekannt ist dass ungleichmassiges Wachstum der paarigen neuro-zentralen Verbindungen zu einer Drehung der Wirbelkorper im Gegensatz zu einer harmonischen Wirbelsaule fuhrt Die folgende Verscharfung der Skoliose kann durch das Wachsen der Wirbelkorper erklart werden

RÉSUMÉ

La cause biologique de la scoliose idiopathique reste inconnue Cependant on a constaté une inégalité de croissance des jonctions entre le point d ossification central et les points neuraux qui peut conduire à une rotation du corps vertébral L aggravation ultérieure de la scoliose peut s expliquer par la continuation de la croissance des corps vertébraux

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FROM THE RADIOLOGIC DEPARTMENT OF ST CANISIUS ZIEKENHUIS NIJMEGEN, HOLLAND

GAMMA ENCEPHALOGRAPHY WITH RADIOACTIVE BISMUTH 206

by

J TH VAN DER WERFF

SELVERSTONE et coll (1949) developed a method by which the high uptake of radioactive phosphorus ^{32}P in tumour cells measured by means of a needle detector could be used for determining the boundaries of a tumour at operation MOORE (1953) showed that the detection and localization of tumours by means of external measurements on the unopened skull was possible This author used diiodofluorescein tagged with ^{131}I and later on ^{131}I human serum albumin (^{131}IHSA) the method in which he placed the Geiger Muller counter on the various parts of the skull was called isotope encephalometry

The diagnosis and localization of brain tumours by external measurements have since been used in many centres other isotopes have been employed successfully the Geiger Muller counter has been replaced by the scintillation counter and the method of automatic scanning has been introduced

A comparison of the various techniques of today makes it difficult to say which localization test gives the best information

Submitted for publication 16 March 1964

SWEET & BROWNELL (1955) have obtained excellent collimation and sometimes spectacular diagrams with positron emitting ^{74}As in combination with counting with two scintillation detectors and an automatic scanning device. Scanning was performed by these workers in two parallel planes, both detectors being opposite to each other. By reason of the costs of the ^{74}As and the equipment, the method is expensive. Also, a difficulty sometimes arises in that an increased uptake of the isotope will be represented by enhanced contrast, not always readily detected by the eye. MALLARD, FOWLER & SUTTON (1961) evolved a refinement of the method: while the scan of normal brain tissue is carried out in black, an increase in the uptake is manifest by a change in colour which is easily detected visually.

A multi-field method has been developed by PLANIOL (1959, 1960). A bathing cap, upon which a number of circular fields are marked, is fitted over the patient's skull. The scintillation detector is positioned successively over all the fields, perpendicular to the skull, the count rates being recorded in a so-called 'gamma encephalogram' from which the localization of any brain tumour may be determined. ^{131}I in the form of ^{131}IHSA is used, which gives better results than the more simple Na^{131}I. The method is much cheaper but naturally requires more work.

Most authors who have published their results with the methods described claim a correct diagnosis in 70 to 90 per cent of cases, although the statistics are difficult to compare.

Soon after ^{206}Bi had been introduced by the present author as a radioactive isotope for medical purposes, MUNDINGER started his investigations into its value for the detection and localization of brain tumours. Extensive experiments on the distribution and course of the activity in more than 500 rats, with various experimental solid and ascitic tumours (ref. 7, 8), were followed in 1956 by localization tests with ^{206}Bi in 9 cases of human brain tumours (ref. 9) in which exact localization was confirmed at operation.

The concentration of ^{206}Bi follows immediately after that in the kidney, spleen and liver in the experimental tumours of rats. The enrichment quotient in the tumour attains a value of 75 to 100, as compared to normal brain tissue, between half a day and two days after the intravenous injection of carrier-free ^{206}Bi nitrate. The biologic half-life in the tumour lies between 6.4 and 7.2 days, and is thus considerably longer than that of ^{131}IHSA.

MUNDINGER mainly used the multi-field test, in which he compared the activity at symmetrically disposed sites of the skull. His results have been published in a number of papers (ref. 8, 9, 10, 11, 12). He also tried to obtain an insight into the type of tumour by repeating the measurements at different times from 1 hour up to 120 hours after the injection.

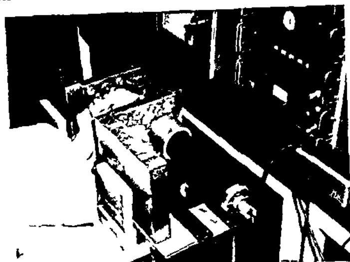


Fig 1 Lead turrett with holes for the measurements of a gamma encephalogram

The various high accumulation factors (against neighbouring areas of comparison) the various degrees of accumulation (percentage rise or fall of the differential counting rates above the tumour area in control measurements) or the different enrichment and accumulation times permit of an indication of the kind of tumour

It is found that glioblastomas and undifferentiated gliomas are characterized by their high accumulation factor, a medium high increase of the degree of accumulation a short to medium long enrichment period and a long accumulation time

Astrocytomas exhibit a lower accumulation factor Their degree of accumulation falls practically exponentially after the one hour test the enrichment period is short and the accumulation period is long

Meningiomas have a low to medium accumulation factor a rapid decrease in the degree of accumulation a long enrichment period and a short to medium long accumulation period

Carcinomatous metastases which also have a low accumulation factor, show a high degree of accumulation and only a short enrichment and accumulation period

MUNDINGER considered that the advantage of ^{206}Bi as compared to ^{131}IHSA lay less in the localization accuracy than in its cellularly bonded and varyingly strong affinity for the different tumours and its definite and long lasting accumulation in the tumour cells

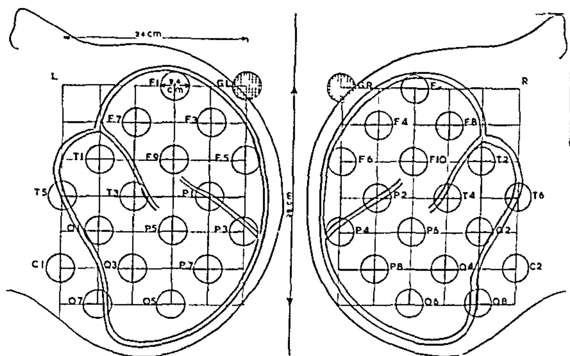


Fig. 2. Distribution of the holes in the side walls of the lead turrett.

As ^{206}Bi is constantly used in our clinic for therapy, and consequently is also available for diagnosis, a number of tests were carried out into the localization of brain tumours; these confirmed MUNDINGER's findings of the usefulness of this radioactive isotope for the purpose.

A special device, mainly based on PLANIOL's method, and with which the counting rates of opposite fields could be easily and clearly compared, has been constructed. In the Planiol method, the activity of the various fields of the right and the left side of the skull in a particular sequence is measured, the *count rates of both sides are recorded on paper and a bilateral gamma encephalogram* is obtained. A third graph, in which the differences of the corresponding fields are plotted, is then constructed so that any existing asymmetry in the uptake and site of origin may be easily detected. PLANIOL placed the detector perpendicularly to the skull so that measurements of the corresponding fields of both sides were not generally opposite to each other. In the method now described, we measure the fields symmetrically disposed on either side by means of the special device (Fig. 1).

Method. The patient lies supine with the head in a turret with 3 cm lead walls. The side walls, which can be moved till they touch the skull, each contain 18 holes, of 2.4 cm diameter, and closed by a removable lead plug

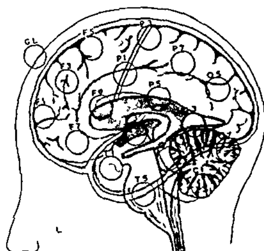


Fig 3 The relation of the positions of the measuring fields to the brain

Each hole has its own indicator and number (Fig 2) The holes of the left wall are G_1 F_1 F_3 F_5 F_7 F_9 T_1 T_3 T_5 P_1 P_3, P_5 P_7, O_1, O_3 O_5, O_7 and C_1 and the opposite holes of the right wall G F^2 F^4 F^6 F^8 F^{10} T^2, T^4 T^6 P^2 P^4, P P^8 O^2, O^4 O^6, O^8 and C^2 With a head of normal size and correctly positioned the axes perpendicular to the planes of the oppositely arranged fields are distributed uniformly through the brain except for the axis G_1—G which grazes the skull (Fig 3)

The lead turret is complemented by a 5 cm thick lead shield which screens off most of the body radiation

Measuring takes place by replacing the lead plugs one by one with a nylon plug This plug is fixed in a hole in the centre of a lead cylinder containing the end of the scintillation detector which is provided with a crystal, 2 4 cm in diameter The high energy quanta are cut off to 0 6 MeV by means of a discriminator in order to limit the effect of the body activity

Instead of recording the count rates measured directly in a right and a left gamma encephalogram as in the Planiol method we made an attempt first to normalize the count rates in order to make the reading of the encephalogram easier This was done primarily because simple recording of the count rates generally revealed a slight asymmetry between the right and left gamma encephalograms, obviously caused by the penetration of some body radiation that is asymmetrically distributed This asymmetry manifests itself in the count rates of the grazing fields G_1 and G which are never quite equal It also appeared that the uptakes in the brain and the skull often differ widely from one patient to another

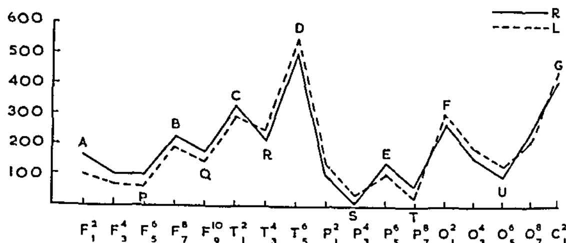


Fig. 4. Normal gamma encephalogram.

The normalization procedure is as follows.

Let $a_{n\,l}$ and $a_{n\,r}$ ($n = 1, 2, \ldots, 17$) be count rates measured respectively at the left and the right side and g_l and g_r the count rates of the grazing fields. We first derive a new series of values $b_{n\,l}$ and $b_{n\,r}$ by subtraction: $b_{n\,l} = a_{n\,l} - g_l$ and $b_{n\,r} = a_{n\,r} - g_r$.

The effect of the asymmetric body radiation is thus decreased.

The so-called normalization factor N, defined by the formula

$$\frac{34 \times 600}{\Sigma a_{n\,l} + \Sigma a_{n\,r}}$$

is then determined. Multiplication of the count rates $a_{n\,l}$ and $a_{n\,r}$ by N would normalize the mean of these values to 600.

When N has been found, a third series of values $c_{n\,l}$ and $c_{n\,r}$ may be obtained by multiplication by N:

$$c_{n\,l} = N \times b_{n\,l} \text{ and } c_{n\,r} = N \times b_{n\,r}$$

The calculation may easily be carried out with a computer. The values $c_{n\,l}$ and $c_{n\,r}$ are then plotted on paper and the normalized gamma encephalograms of both sides of the head are obtained.

It was found that the normalized gamma encephalogram invariably has the same appearance in a normal symmetric skull and contains a number of positive peaks A, B, ..., G, and negative peaks P, Q, ..., U (Fig. 4). This means that any abnormality in the appearances that cannot be explained by statistical errors in the count rates must necessarily be caused by a pathologic change. These deviations often show themselves in the peaks, which may be reduced, absent, or even reversed.

It must be emphasized that the normalization process does not change the character of either part of the encephalogram. Indeed, the subtraction of the count rates of the grazing fields, from those of the other fields on either side, will only reduce the level of both parts of the encephalogram, at the same time

effectuating a correction of the asymmetric body radiation, as experience has shown This reduction may go so far that some parts of the diagrams pass the zero line However, the character of the two parts of the encephalogram is not affected by the subtraction, and this is also true of the multiplication of all the count rates by the normalization factor The factor depends only on the dose given and on the uptake of all participating tissues at the moment of measuring

The number 600, to which the mean of all measured count rates are raised or lowered, is chosen only for convenience in order to make the different encephalograms more comparable

As the size of the head even in adults, often differs more or less widely, the lead side walls may if necessary be replaced by others, with slightly smaller holes that may also be placed closer together It has been found that only three sets of side walls are necessary for obtaining an encephalogram comparable with any head

MUNDINGER used ^{206}Bi nitrate but we found no difference in the results when using other inorganic compounds of ^{206}Bi An intravenous injection of 0 3 mCi carrier free ^{206}Bi acetate is given, and the measurements are carried out 12 to 24 hours later The examination requires no particular preparation of the patient but a great deal of attention has to be paid to the correct positioning of the head in the turret The patient must be completely still during the examination luminal is therefore given previously when it is considered necessary

The necessity of confining the entire examination to about one hour limits the counting time to one minute for each hole Only the grazing fields are measured 2 min before and 2 min after the measuring of the other holes on either side in order to reduce statistical errors as far as possible The count rates are then processed in the computer and the normalized gamma encephalograms is plotted

The analysis of the gamma encephalogram certainly requires some experience and may be facilitated by drawing arrows pointing upwards as an indication of increased uptake for every field where deviations from the normal encephalogram are observed These deviations are transferred to a scheme of the head in which the fields of both sides are indicated solid circles denoting greatly increased uptake hatched circles moderately increased and dotted circles decreased uptake

The normal and the pathologic encephalogram The radiation that reaches the crystal of the detector placed before a hole of the lead turret consists of 5 components

1 The direct radiation from the radioactive bismuth taken up by the bony skull

2 The direct radiation from the radioactive bismuth taken up by the brain tissue

3 A negative component due to the absorption of the direct radiations by the bony parts of the skull and by the brain tissue transversed

4 Some radiation scattered by the brain tissue

5 A small part of the slightly asymmetric body radiation that passes along the closing lead screen and the radiation from the environment

The components (4) and (5), being already small in themselves, are furthermore eliminated by the normalization process The absorption component (3) *is never negligible It reduces the count rates measured but will be in*dependent of the condition of the brain As for the components (1) and (2), experiments in animals have shown that the uptake of ^{06}Bi in bone is at least 10 times as high as in the normal brain It may therefore be expected that the shape of the normal gamma encephalogram will be largely determined by the radiation *from the bony skull This was confirmed* by an accidental observation

A patient was given 0 3 mCi ^{06}Bi for gamma encephalography the following day but died during the night The encephalography was performed post mortem The brain was then removed and a further encephalography carried out, now on the empty cranium The result was a perfectly symmetric encephalography with all the characteristic normal features

The fact that the uptake in the normal brain is very low may easily be *understood by a consideration of the fact that the blood brain barrier prevents* non physiologic agents circulating in the blood from entering the brain cells

MUNDINGER has shown, however, that the blood brain barrier breaks down in many tumours and their uptake may rise up to between 50 *and 100 fold* of the uptake of the normal brain This makes it clear that the presence of a tumour may affect the gamma encephalogram in such a way as to make a localization possible

Various studies on the blood brain barrier (cf BAKAY 1956) have clearly shown that other pathologic conditions may also cause such a breakdown Injuries, such as stab wounds and electrocoagulation, cause a temporary upset in the permeability of the barrier BROMAN *(1944, 1949)* also reported a *similar* change in experimental micro embolisms and in other cerebrovascular disorders

The uptake has been shown to be considerable in infected areas of the brain, especially during the acute phase This high uptake is however mainly located *in the capsular* wall *of* any abscess that may arise

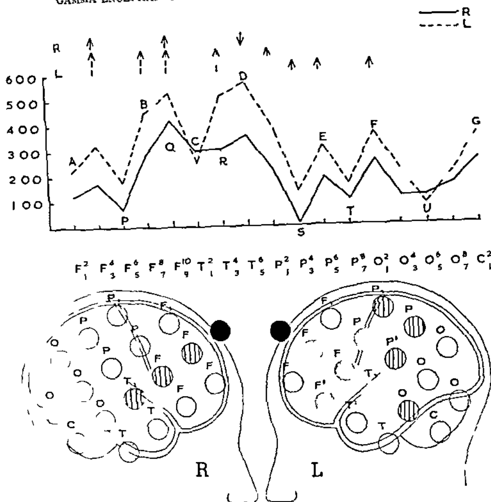


Fig 5 Encephalogr m and d st bution of holes in a case of astrocytoma

It is clear that all these factors may determine the characteristics of the gamma encephalogram Very little is known of the changes in the blood brain barrier in chronic disorders

Results

Two hundred and sixteen gamma encephalograms have been performed since the construction of the measuring device and tests to develop the method These examinations were not restricted to cases of brain tumour but were carried out in a number of other cases as well

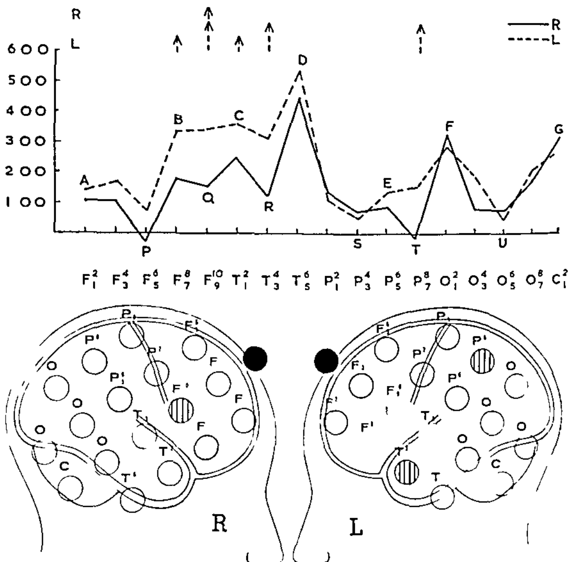


Fig 6 Encephalogram and distribution of holes in a case of glioblastoma

Normal encephalograms were invariably recorded in cases without any central neurologic signs and they were also observed in a few cases in which some kind of cerebral disorder was certainly present

Tumours, because of their highly increased uptake, will nearly always give rise to abnormal encephalograms The deviations found by careful analysis of the graphs are then located in adjacent fields and form a closed group Abnormal encephalograms caused by other cerebral disorders mostly show no such grouping of deviations Both parts of the encephalogram are sometimes quite normal or merely indicate an asymmetry of the hemispheres, on the other hand they may be markedly irregular

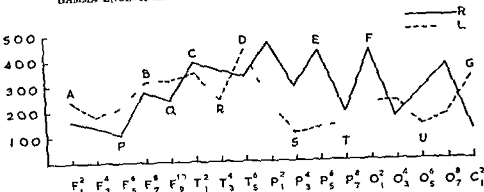


Fig 7 Encephalogram in a case of polycythaemia vera

A tumour was found during the last two years in 64 cases at operation In 56 cases (= 87 %) the tumour and its localization had been predicted by the analysis of the encephalogram In 2 cases of extensive meningiomas the irregularities in the graph were so complicated that no exact diagnosis was possible in another case of two small meningiomas the graph was normal

As it is impossible to review the whole material in detail, some examples of abnormal gamma encephalograms will be given The reader is invited to compare these with the normal encephalogram in Fig 4

Case reports

Case 1 (Fig 5) The encephalogram had asymmetric and pathologic tracts (L -> R) with bilateral reversal of the peaks Q and R and increased uptake *in the fronto-temporal region* A tumour found at operation in the left paramedial fronto-temporo-basal region proved to be an astrocytoma

Case 2 (Fig 6) Pathologic deviations especially in the left fronto-temporal track with a reversal of the Q peak as well as the T peak were evident At operation a glioblastoma was present in the left fronto-temporal region

Case 3 (Fig 7) Pathologic tracks on both sides no localizing focus The patient was known to have been suffering for more than 30 years from polycythaemia vera he was physically unbalanced at the time of examination and had occasional temporary diplopia The deviations in the gamma encephalogram *were probably* caused by multiple small atrophic regions remnants of brain embolisms

Case 4 (Fig 8) An obvious reduction of the blood brain barrier on the left side was evident Symptoms had started some days after vaccination against smallpox with headache and fever dizziness and hypometria Romberg's sign was positive backwards to the left The deviations in the encephalogram were probably caused by an encephalitis postvaccinalis which caused a breakdown of the blood brain barrier on the left side

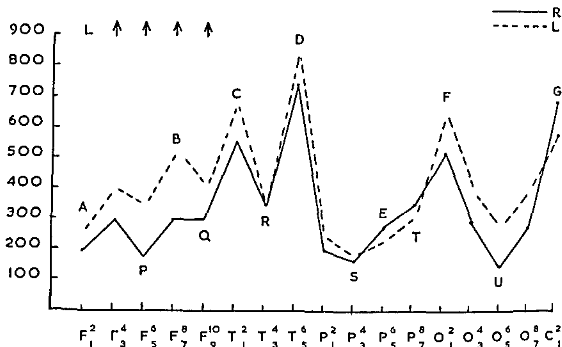


Fig 8 Encephalogram in a case of encephalitis

Discussion and conclusions

^{131}IHSA was used by PLANIOL for her method of brain tracing and prompted the author to perform a few gamma encephalograms with this radioactive isotope in normal cases It was confirmed that ^{131}IHSA gave rise to a gamma encephalogram very similar to the characteristic one obtained with ^{206}Bi The same positive peaks were evident, yet the two encephalograms were not identical, probably on account of the different energies of the radiations emitted by the two different isotopes Although it is not definite that all abnormal encephalograms obtained with ^{131}I or ^{206}Bi will always show the same degree of irregularity, it is probable that both radioisotopes can be used for the detection and localization of brain tumours

Nevertheless ^{206}Bi has a number of advantages over ^{131}I

1 The cellularly bonded and varying strong affinity of ^{206}Bi for the different tumours with a definite and long lasting accumulation in the tumour cells (MUNDINGER 1962, ACKERMAN & PLANIOL, personal communication, and MATTHEWS 1963)

2 The low radiotoxicity of ^{206}Bi (20 times less than that of ^{131}I), mainly due to the absence of beta radiation

3 Previous blocking of the thyroid with inactive iodine is always necessary with ^{131}I

No particular preparation of the patient is necessary with ^{206}Bi

This isotope is not however always the one of choice in all the present methods The necessary heavy screening of the detector precludes its employment in the Planiol method Furthermore it cannot be employed in the Sweet Brownell method one that depends on the use of a positron emitting radioisotope

As for the detection and localization of brain tumours the results with all methods are about equal The same holds good even for automatic scanning with positron emitters The practical results are however no better than with multi field methods although on account of perfect collimation very small increases in the uptake of the isotope may be detected

The advantage of the method described would appear to lie in the fact that a normal brain in a normal skull produces a characteristic gamma encephalogram in which any significant deviation must be caused by some cerebral lesion whether it be a tumour or not Considerable information about the general condition of the brain may thus be obtained It must, however again be emphasized that a normal encephalogram does not necessarily exclude a cerebral disorder

SUMMARY

A new method of gamma encephalography in which pure gamma-emitting radioactive bismuth ^{206}Bi was used in a material of 216 cases is described Confirmation of the findings was obtained at operation in a large percentage of cases Although normal encephalography does not necessarily prove that the brain is normal any deviations are always an indication of pathologic conditions

ZUSAMMENFASSUNG

Eine neuartige Methode der Gamma Enzephalographie mit Hilfe von gammastrahlendem reinem Bismuth ^{206}Bi wurde an einem Material von 216 Fallen ausprobiert Ein grosser Teil der Falle konnte operativ bestatigt werden. Obwohl eine normale Enzephalographie keineswegs beweist dass das Gehirn normal ist so bedeuten doch abnormale Befunde dass Gehirnveranderungen vorliegen

RÉSUMÉ

Description d'une nouvelle méthode de gamma-encéphalographie au moyen du bismuth radioactif ^{206}Bi émetteur gamma pur qui a été appliquée sur 216 cas Les résultats ont été confirmés par l'opération dans une grande proportion des cas Bien qu'une gamma-encéphalographie normale ne soit pas nécessairement la preuve que le cerveau est normal toute anomalie est toujours le signe d'un état pathologique

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FROM THE DEPARTMENTS OF RADIATION THERAPY (DIRECTOR PROF M LINDGREN) RADIATION PHYSICS (DIRECTOR PROF K LIDEN) AND ROENTGENDIAGNOSIS (DIRECTOR PROF O OLSSON) UNIVERSITY OF LUND SWEDEN

EXPERIENCES WITH GAMMA ENCEPHALOGRAPHY

Part II

by

S Ahlstrom B Bodforss and S Cronqvist

The purpose of this paper is to report experiences with gamma encephalo graphy in an unselected series of 113 cases of cerebral disorders These were referred for gamma encephalography from the neurosurgical, neurologic and radiotherapeutic clinics The indication for the examination was the clinical suggestion of a cerebral lesion no further selection of cases was made Ten normal cases were studied for comparison

RISA was used in 110 cases 6 of these receiving the substance on two occasions and one on three different occasions The shortest interval between repeat examinations was 6 weeks Five of the 110 cases were excluded because of incomplete examinations Lugol was administered with the RISA 10 drops being given three times a day for three days to block the thyroid scanning of the gland has shown this premedication to be effective in decreasing its uptake of radioactive ^{131}I

RISA was injected intravenously in 104 examinations and intra arterially in 14 examinations at the time of carotid angiography in these 14 cases

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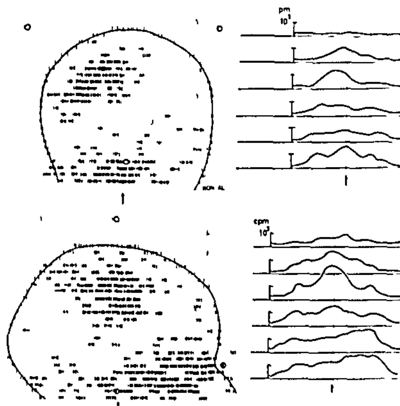


Fig. 1. Case of meningioma. To the right profile diagrams showing increased activity within region corresponding to that seen in the scintigrams.

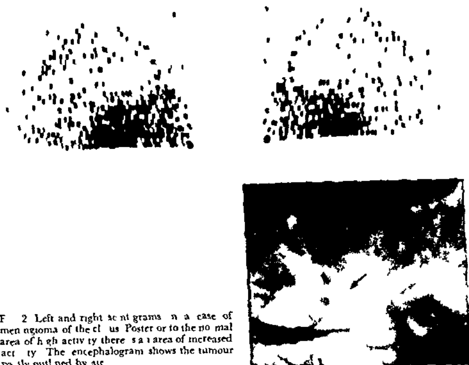
scanning of the skull was performed immediately after the injection and again at 24 hours. When the injections were made intravenously, scintigrams were obtained at 2 and 24 hours in 29 cases, and only at 24 hours in the remaining cases.

Neohydrin ($10 \mu Ci/kg$ bodyweight) was used as tracer substance in 5 cases and scanning was performed at 6 hours (BLAU & BENDER 1960). Polyvinylpyrrolidone ($100 \mu Ci$) was employed in 8 cases, with scanning at 24 hours and 4 days.

The results of the examinations were evaluated by each member of the team and later discussed and compared with the neuroradiologic examinations. The gamma encephalographic findings were verified by roentgenologic findings, operation, or histologic section.

A. Meningeoma (9 cases)

Gamma encephalography was positive in all nine cases. An intense isotopic uptake in the lesion was indicated by a well demarcated area with a regular



F 2 Left and right scintigrams in a case of meningioma of the clivus Posterior to the normal area of high activity there is an area of increased activity The encephalogram shows the tumour partly outlined by air

margin separating it from the surrounding brain tissue (Figs 1 11a) it was localized in the fronto parietal region in one case the parietal in four, the temporal region in three, and in the posterior fossa in one case The position of the hyperactive area immediately adjacent to the cranial vault was evident in seven of the cases Gamma encephalography was difficult to interpret in the case with meningeoma in the posterior fossa (Fig 2) The tumour was growing on the clivus and the area of hyperactivity was partly superimposed on the normal activity of the temporal region

Pathologic encephalographic findings were recorded in all the eight cases examined Angiography was performed and the presence of pathologic vessels was definite in five These vessels emanated from the external carotid artery in one case from the internal carotid artery in two and from both these arteries in two cases The combined radiologic findings permitted the diagnosis of meningeoma in eight cases while in the ninth the diagnosis was considered probable All cases were operated upon and the diagnoses were verified

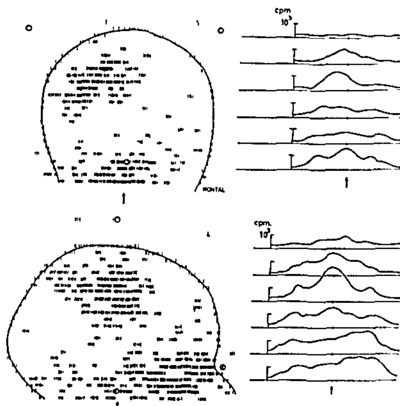


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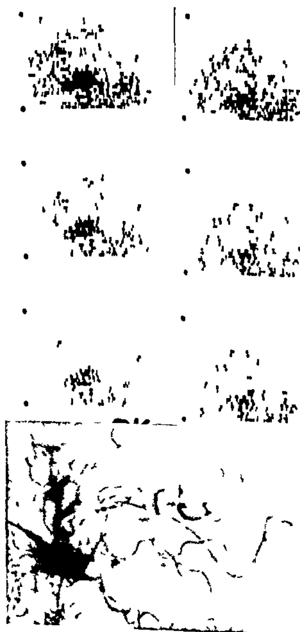


Fig 3 R ght lateral sc nt grams with success ve suppression in a case of malignant glioma with neohydr n at 6 hours and RISA at 24 hours respectively after njection Area w th increased activ ty in right temporal reg on The angiogram shows d splacement of normal vessels and pathologic ves el indicat ng tumour in the anterior temporal region

The changes at gamma encephalography in cases of meningeoma are thus characteristic and consist of an intense uptake within a well defined area The diagnosis of meningeoma should be possible if due consideration is given to the localization of the hyperactive area *in relation to the midline and* skeletal structure Additional diagnostic aid may be obtained by repeat scintigrams High activity in the lesion is recorded at 2 hours and will remain unchanged at 24 hours (Fig 11a)

B Brain tumours other than meningeoma (32 cases)

A pathologic scintigram with an area of increased uptake was recorded in 26 out of these 32 cases The area generally had an irregular outline with *variation in activity from case to case A gradual conversion from the area with* increased activity to surrounding normal tissue was noted

Angiography was performed in all cases and encephalography in 23 cases Positive radiologic findings in combination with clinical data permitted the diagnosis of a malignant intracerebral tumour in 25 cases (malignant glioma in 14, astrocytoma in 9 and oligodendroglioma in 2 cases), two other cases were diagnosed as pinealoma and cholesteatoma, respectively Additional confirmation of the diagnosis was made in 19 cases by histologic section The determination of the specific type of lesion was not possible in 5 cases, *one of these being a case of tumour of the septum pellucidum and four* being cases of avascular intracerebral expansive process The diagnosis in these four cases was, however, definitely that of a tumour since progressing changes were recorded at the repeated neuroradiologic examinations in one case and encephalography in a second case disclosed an expansive process within the thalamic region, with displacement and compression of the posterior part of the third ventricle In the third case, angiography as well as encephalography revealed an expansive lesion within the central part of the fronto parietal region, and repeated EEGs showed progress of the pathologic changes This was also seen in the fourth case, together with clinical and radiologic signs of a space occupying process in the left parietal region

Pathologic vessels were found in 16 of 26 cases with positive scintigrams Twelve of these were gliomas (see Figs 3, 4 7, and 11c) and four were astrocytomas (see Fig 5) In none of six cases with a negative scintigram did angiography reveal pathologic vessels In one of these, a cholesteatoma, could no such vessels actually be expected In two, the lesion was localized within regions in which angiography is of doubtful value Among the four cases of astrocytoma, two were not verified by histologic section, pathologic vessels were present in both Two cases of oligodendroglioma that showed no patho

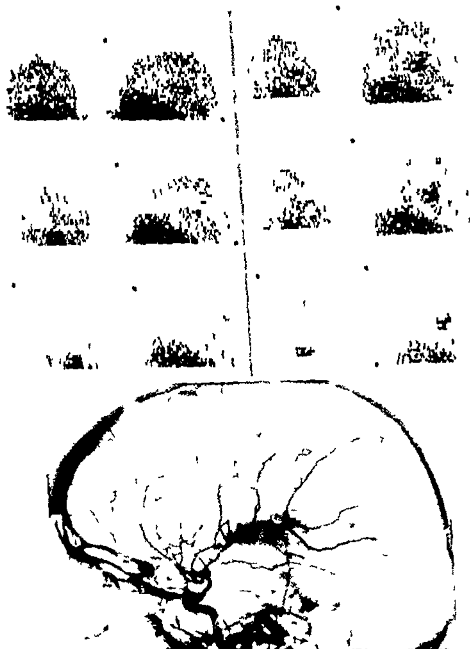


Fig 5 Frontal and left lateral scintigrams with successive suppression in a case of malignant astrocytoma growing centrally within the left parietal region at respectively 2 hrs (left rows) and 24 hrs (right rows) after injection Changed background and increased activity The angiogram shows displacement of normal vessels and no pathological vessels



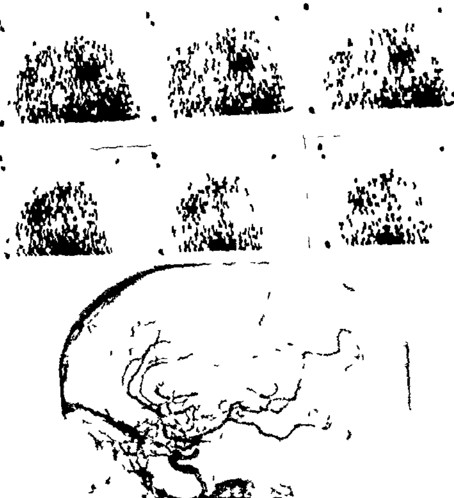
Fig 4 Left lateral scintigrams in a case of malignant glioma The area with increased activity is irregular in outline

logic vessels in the angiogram but had a distinct area of hyperactivity are of special interest (Fig 6) This area, as in the cases of malignant glioma and astrocytoma, was not well defined in relation to the surrounding tissue

Gamma encephalography was positive in all the 14 cases of malignant glioma, in eight of the 9 cases of astrocytoma, and in the two cases of oligodendroglioma Negative findings were recorded with the pinealoma, the cholesteatoma and the tumour of the septum pellucidum Two of the four cases with avascular expansive process had positive scintigrams

The gamma encephalographic and the neuroradiologic findings differed in three cases The area of increased uptake in one case was localized somewhat frontal to a highly vascular lesion evident in the angiogram In two other cases the size of the lesion in the scintigram differed from that in the angiogram, the scintigram in one of them showed activity within a region smaller than that circumscribed by pathologic vessels and in the second, with no pathologic vessels in the angiogram, the size as determined by displacement of cerebral vessels was larger than judged by the gamma encephalograms This discrepancy was most probably due to edema around the lesion, depicted as an area of hyperactivity encircled by a zone of decreased isotope uptake (Fig 7)

There was thus good agreement, in all but three of the 26 cases with positive scintigrams, between the size of the expansive process as determined radiologically and by gamma encephalography The activity within the tumour varied Generally, it may be said that it was highest in malignant gliomas The area of activity had an irregular border Repeat examinations will increase the possibility of establishing a differential diagnosis, as the activity in tumours of this type is greater at the 24 hour than at the 2 hour scintigram (Figs 5, 11c)



Fi 7 Rigl t lat ral sc nti ams (upper row) and a p p ojecti ons (lowe ow) with success ve suppress /n in a case of malignant glioma Decreased activ ty within zone encircl ng irregular a ea with i creased activity The a giogram i w thout p thol g c vessels only sl ght di placement of arter es

in 8 of these 10 angiograms The 5 encephalograms were all abnormal in one of these with a lesion in the third ventricle the angiogram was interpreted as normal

Autopsy was performed in 9 cases Metastases in the brain were found in 6 cases in the bones of the skull and meninges in two cases and in the meninges alone in one case

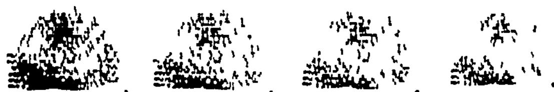




Fig 6 Left lateral scintigrams in a case of oligodendroglioma There is an area of *increased activity with irregular borders* Angiogram from venous phase shows veins encircling part of the tumour

C Metastases (23 cases)

There were 23 cases in our series with known malignancy elsewhere and clinical signs of a cerebral lesion Gamma encephalography disclosed pathologic features in 16 cases (Figs 8 and 9) Definite increased activity within circumscribed areas was evident in 15 cases and in one case gamma encephalography suggested a lesion The isotope uptake was generally very marked The demarcation between surrounding tissue was either vague and irregular or definite and regular In four cases the area of increased activity was encircled by a zone, with decreased or no activity, separating it from surrounding tissue with normal background activity Multiple hyperactive areas were noted *in three cases, and gamma encephalography in two cases revealed a* lesion in the bones of the skull

Radiologic examinations were performed in 18 cases, in 2 of these they had been confined to the skull and revealed bone destruction Angiography was performed in 16 and encephalography in 5 cases Ten of the 16 angiograms disclosed changes, which were multiple in three pathologic vessels were found

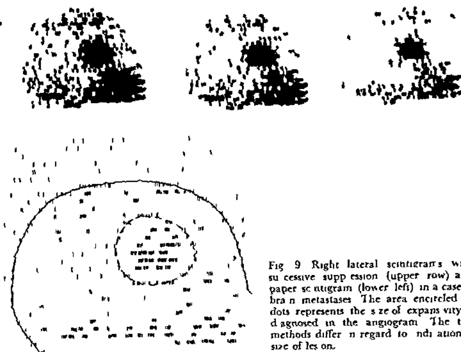


Fig 9 Right lateral scintigrams with successive suppression (upper row) and paper scintigram (lower left) in a case of brain metastases The area encircled by dots represents the size of expansivity as diagnosed in the angiogram The two methods differ in regard to indication of size of lesion.

co existence of oedema around the lesion commonly noted with metastatic brain lesions The oedema was also seen in the scintigram as a zone of decreased activity surrounding the lesion Pathologic vessels were evident in eight cases all of them with a positive gamma encephalography

Two cases were of special interest

Case 9? (Fig 8) Female aged 56 with a tumour of the sweat glands in the soft tissue of the skull Multiple pulmonary metastases were present in 1961 and responded to radiation therapy In January 1962 slight right sided hemiparesis and epileptic fits were noted Left sided carotid angiography showed multiple metastases in the left parietal region and gamma encephalography increased isotope uptake in same region Treatment telegamma cobolt (4 ,00 R/15 days) In March 1962 the angiogram and encephalograms revealed a decrease in size of the metastases and the clinical condition was improved In November 1962 encephalography and angiography were normal and the patient had no symptoms

Case 9 Female aged 79 with carcinoma of the breast The radiologic examination of the skull revealed destruction of the frontal area Gamma encephalography disclosed an increased isotope uptake within the corresponding area there was marked decrease in the size of the area of increased uptake following radiation therapy

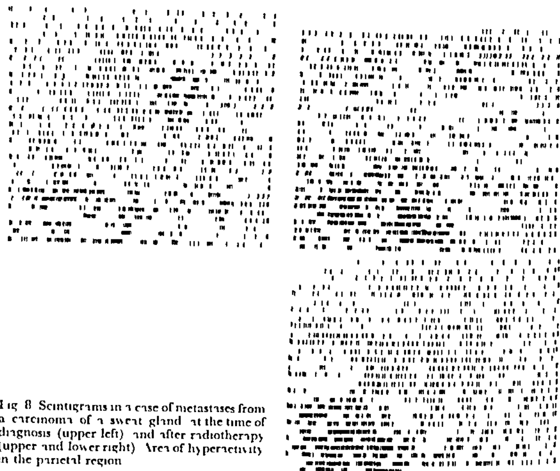


Fig 8 Scintigrams in a case of metastases from a carcinoma of a sweat gland at the time of diagnosis (upper left) and after radiotherapy (upper and lower right) Area of hyperactivity in the parietal region

Pathologic findings were noted in 3 of 5 cases examined only by gamma encephalography Of the 18 cases in which roentgenologic examinations were also performed, good correlation existed in 16 Gamma encephalography rendered only vague indications and the roentgen examination was incomplete in one of these cases In another case, with an extensive area of increased activity in the suprasellar region to the left of the midline, only right sided carotid angiography was performed, the findings were normal Autopsy revealed metastases to the meninges in this case

Multiple small metastases were found at autopsy in 3 cases, gamma encephalography and the radiologic examination being positive in one of these The metastases were found to measure less than 10 mm in the other two cases both with negative gamma encephalography

It is interesting to note that in four cases the area of increased uptake in the gamma encephalograms was small in comparison to the size of the lesion in the roentgen films (Fig 9) These differences are explained by the probable

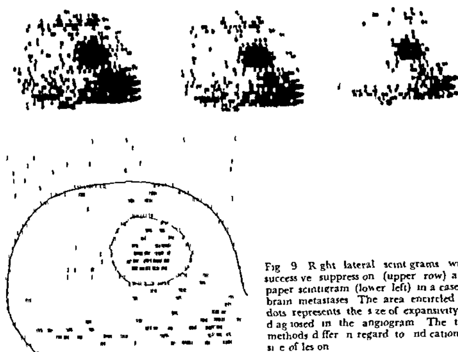


Fig 9 Right lateral scintigrams with successive suppression (upper row) and paper scintigram (lower left) in a case of brain metastases The area encircled by dots represents the size of expansivity as diagnosed in the angiogram The two methods differ in regard to indication of size of lesion

co-existence of oedema around the lesion commonly noted with metastatic brain lesions The oedema was also seen in the scintigram as a zone of decreased activity surrounding the lesion Pathologic vessels were evident in eight cases all of them with a positive gamma encephalography

Two cases were of special interest

Case 92 (Fig 8) Female aged 56 with a tumour of the sweat glands in the soft tissue of the skull Multiple pulmonary metastases were present in 1961 and responded to radiation therapy In January 1962 slight right sided hemiparesis and epileptic fits were noted Left sided carotid angiography showed multiple metastases in the left parietal region and gamma encephalography increased isotope uptake in same region Treatment telegamma cobolt (4 700 R 25 days) In March 1962 the angiogram and encephalograms revealed a decrease in size of the metastases and the clinical condition was improved In November 1962 encephalography and angiography were normal and the patient had no symptoms

Case 9 Female aged 79 with carcinoma of the breast The radiologic examination of the skull revealed destruction of the frontal area Gamma-encephalography disclosed an increased isotope uptake within the corresponding area there was marked decrease in the size of the area of increased uptake following radiation therapy

Repeat encephalography examinations in these two cases clearly indicated the regression of the metastases after radiation therapy

D Other diseases of central nervous system (30 cases)

This group with different neurologic signs was examined by radioactive isotopic and neuroradiologic procedures to verify or exclude an expansive lesion In the majority of cases the radiologic examinations were normal or revealed changes incompatible with the diagnosis of a tumour In a few cases, with signs of an expansive lesion, further observation revealed regression of the clinical signs and/or radiologic changes The cases have been grouped according to their more obvious clinical signs There were 12 cases with *epileptic seizures*, 7 *with paresis*, and 3 *with vertigo*, *psychiatric signs* were predominant in 3 other cases Acute increased intracranial pressure, acute headache with paresis of the abducens nerve, unilateral exophthalmus, confusion and trigeminal neuralgia were present in 5 cases, respectively

Of the 12 cases with epileptic seizures, only two had abnormal although vague gamma encephalographic findings, the neuroradiologic examinations also revealed changes A follow up examination in one of these cases disclosed regression of the clinical as well as the radiologic signs, and in the other case regression of the clinical signs and encephalographic changes took place *The diagnosis by exclusion suggested a probable vascular origin of the lesion* In the remaining 10 cases with negative gamma encephalography, three had no abnormal radiologic findings, four had changes due to atrophy, and one case each a small arteriovenous malformation, an arterial aneurysm, and a posthaemorrhagic cyst, respectively

The gamma encephalographic examination was normal in the seven cases with paresis, the radiologic examination was normal in only one Two had central atrophy, one thrombosis of a branch of the middle cerebral artery, and three had an expansive process The onset of symptoms was acute in these last three cases Further radiologic follow up revealed regression of the initial changes The symptoms and signs were considered to be due to a vascular lesion

Vertigo was the main symptom in 3 cases In one of these the isotope uptake was increased in the gamma encephalograms within a region corresponding to an avascular area present in the angiogram *A haematoma was found* at operation The other two cases had normal encephalograms one had normal radiologic findings and the other cortical atrophy Gamma encephalography was negative in the three cases with psychiatric signs, two of which had atrophy diagnosed by encephalography



Fig 10 Left lateral scintigram with successive suppression in a case of abscess following chronic otitis Area with increased activity in temporal region

Of the five remaining cases with different neurologic signs three had normal gamma encephalograms with radiologic changes in one of these In the fourth case an increased isotope uptake was noted within an irregularly outlined area in the left parietal region no corresponding radiologic changes were evident The case was admitted to hospital on account of acute headache and papillary oedema as signs of increased intracranial pressure Increasing spasticity developed in both legs Subsequently an enlargement of lymph nodes occurred and biopsy revealed sarcoidosis Improvement was observed in the neurologic signs as well as in the size of the lymph nodes after cortisone treatment and a second gamma encephalography was normal The fifth case was one of chronic bilateral otitis A state of confusion suddenly developed and angiography as well as encephalography disclosed an expansive process within the left temporal lobe Gamma encephalography was positive with an increased activity within the corresponding region The diagnosis of an abscess was made When the signs subsided repeat neuroradiologic examinations and gamma encephalography demonstrated regression of the pathologic changes

Only 5 of the 30 cases in this heterogenous group thus had abnormal gamma encephalograms These included one case of an intracerebral haematoma one of intracerebral sarcoidosis and a third case with an abscess In the two remaining cases in which the gamma encephalographies were vague radiologic signs of an intracerebral expansive process were present Regression of the changes and the signs were compatible with the clinical diagnosis of a vascular lesion

Eight cases in the entire series had clinical and radiologic evidence of a vascular lesion Two of these were verified at operation as cases of intracerebral bleeding another had thrombosis of the middle cerebral artery The gamma encephalograms were abnormal in three of the eight cases The interval between the onset of the signs and the isotope examination varied between

3 weeks and 18 months, only 24 hour scintigrams were obtained and a specific diagnosis was not possible by gamma encephalography, a definite diagnosis should however be arrived at from repeat examinations because the uptake is usually higher at 2 hours than at 24 hours.

Postoperative scanning (14 cases)

The common denominator in this group, wholly of tumour cases, is surgical intervention prior to the isotope examination. The isotope distribution undoubtedly is influenced by surgical procedures, the scintigram presenting an increased uptake in the region of the operation. The area of hyperactivity seemed to be confined to the periphery of the skull and its soft tissue. No definite increased uptake in the brain tissue damaged at operation was observed, although an increase is difficult to evaluate, for the region in question is superimposed upon the hyperactive area in the periphery of the skull. This overlapping also caused difficulties in evaluating the size of the expansive process, all of which in this group had increased isotope uptake in the encephalograms. The 14 cases included 6 malignant gliomas and 7 astrocytomas. The fourteenth case, one of a tumour with pathologic vessels in the right thalamic region, had no biopsy but right lateral ventricular puncture placed the case in this group. Angiography had been performed in 13 of the 14 cases and pathologic vessels were present in six. The interval between the surgical intervention (operation, needle biopsy or ventricular puncture) and gamma encephalography varied from 1 week to 14 years. It was evident that the closer the interval, the more obvious the changes observed. A better knowledge of these changes is necessary for a correct estimation of a recurrence after treatment.

Discussion

The isotope examinations were not confined to cases with cerebral tumours but performed on an unselected series of neurologic disorders. Excluding the 10 normal cases and the 5 with inadequate scintigrams, 69 (63 %) of the 108 cases had abnormal gamma encephalograms. Neuroradiologic examinations had been performed in 103 cases with abnormalities in 89 (86 %), abnormal gamma encephalograms were obtained in 67 (65 %) of these.

Of the 78 cases with primary or metastatic neoplasms gamma encephalo

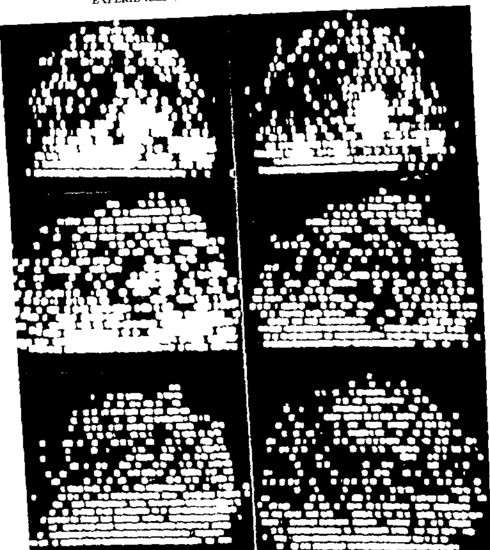


Fig 11 Scintigrams at 2 hrs (left row) and 24 hrs (right row) after injection of RISA in cases of meningioma (upper row) intracerebral bleeding (middle row) and malignant glioma (lower row)

graphy was positive in 62 (79 5 %) and the neuroradiologic examinations positive in 68 (87 5 %)

The pathologic scintigram and its correlation with radiologic examinations have been discussed Because of this only a short survey will be given of the changes observed in the scintigrams in the different groups of cases

Meningeomas presented a well circumscribed area of increased uptake. The hyperactivity within this area was marked (Fig 11a). This was in contrast to that noted in the second group, consisting of cases with brain tumours other than meningeomas. The hyperactive area in this group had irregular borders and the activity within the lesion differed from case to case (Figs 3, 4, 5, 6, 7, 11c). In 3 of the 26 cases of intracerebral tumours, the gamma encephalograms were normal. A normal gamma encephalography, in the presence of an intracerebral tumour, is not surprising since one of the conditions for diagnosis is an uptake of such a degree as to be distinguishable from the normal background activity. As pointed out earlier, the enrichment quotient in tumours for ^{32}P is reported to vary with the kind of tumour, and it seems probable to assume that this is also the case with the isotopes used in this study. While metastases, meningiomas, and malignant gliomas generally have a high enrichment quotient, with astrocytomas and oligodendrogliomas it is very low. As has been shown by BAKAY, differences in activity of similar magnitude are noted even within the normal brain (^{32}P studies). The conditions for diagnosing an astrocytoma as well as an oligodendroglioma are consequently not favourable. Both oligodendrogliomas in this series had, however, a positive gamma encephalogram (Fig 6).

Cases with intracerebral metastases regularly showed a very marked hyperactivity within the lesions although the border towards the surrounding normal brain tissue was generally irregular (Figs 8, 9). In two cases, the metastatic lesion was localized in the calvarium, and gamma encephalography in both revealed hyperactivity within the corresponding area. As might be expected, no principal difference existed between the scintigrams in cases with intracerebral tumours and from those with signs of recurrence. Following surgery, activity was also evident in the periphery of the skull in the region of the operation. Five cases with abnormal scintigrams were found in the large *group of 30 cases with different neurologic signs*. The clinical diagnosis was abscess in one case (Fig 10), sarcoidosis in one and an avascular lesion in three cases. No characteristic features permitted conclusions as to the diagnosis.

The gamma encepahlograms were abnormal in only 3 of the 8 cases with signs and symptoms compatible with the diagnosis of a vascular lesion. It is interesting to note that gamma encephalography in these three cases was carried out within 4 weeks from the onset of symptoms while in the remaining 5 cases the interval varied from 5 weeks to 18 months. It therefore seems probable that the time elapsing between the vascular accident and gamma encephalography may influence the isotope distribution.

All the cases were not examined both at 2 and 24 hours. However, the present

limited experience from cases examined in this manner is the same as that reported by other authors i e in a 2 hour scintigram meningioma and haematoma will show marked activity and glioma little or no activity In comparison a 24 hour scintigram will reveal practically no change in activity in a meningioma, a decrease when a haematoma is present and a marked increase in the case of a glioma A metastatic lesion will generally show marked activity at 2 hours and a further increase at 24 hours (Fig 11 a c)

Repeat examinations were utilized by WENDE who using the technique of PLANIOL compared the different activity curves obtained He succeeded in determining the nature of the tumour in no less than 79 5 % of cases DI CHIRO who performed examinations only at 24 hours was successful in 52 % of cases Repeat examinations are of great importance and should, if possible be regularly applied However, the single scintigram is useful in diagnosing the nature of a lesion if localization and configuration of the area with increased activity as well as the degree of hyperactivity are considered

The localization of the lesion in the present series does not seem to have influenced the evaluation of the scintigram None of the lesions was localised in regions concealed by normally hyperactive areas in the 10 negative gamma encephalographies in cases with space occupying lesions demonstrated by other methods

It has already been pointed out that the presence of pathologic vessels in the angiogram is not necessary for the production of a positive scintigram In the entire series there were 65 cases with a positive gamma encephalogram in which angiography had also been performed in only 35 of these cases were pathologic vessels noted in the angiogram On the other hand in no case with a negative scintigram did the angiogram reveal any pathologic vessels The area with increased uptake was surrounded by an area of decreased activity in some of the cases with intracerebral metastatic foci (Fig 9) and in one case with a malignant glioma (Fig 6) It is probable that this phenomenon was due to oedema encircling the tumour an effect known to occur in cases with rapidly growing tumours In favour of this theory is the fact that the displacement of vessels in the angiogram in these cases indicated an expansivity larger than that apparent from the gamma encephalogram It is evident that the latter examination may help in the differential diagnosis in cases with an avascular expansive process of the brain

The two cases with metastasis treated by radiation therapy are of particular interest (Fig 8) Repeat gamma encephalography disclosed regression of the changes Further studies with gamma encephalography before and after radiation therapy are in progress in a series of cases with intracerebral tumours and metastases

Conclusions

The uptake in intracerebral lesions of the three different substances, RISA, Neohydrin and PVP appears equally good, although RISA in comparison with the other two substances has advantages in brain scanning. A scintigraph with a photoscanning attachment in combination with a magnetic tape recorder permitting repeated registration with successive suppressions of activity appears to constitute the most satisfactory apparatus. It will be necessary to perform further studies on the normal variations in activity in order to gain more experience. *It is further evident that gamma encephalography* at 2 and 24 hours is of the utmost diagnostic value, and that in cases with angiographic evidence of an avascular process, it is of definite diagnostic assistance.

Repeated gamma encephalographic examinations before and after operation or radiotherapy may help in determining regression or recurrence of a *lesion*.

We do not think that gamma encephalography should be used as the only method for confirming or excluding a clinically suspected brain lesion. There can be little doubt that the combined use of gamma encephalography and conventional neuroradiologic examinations will increase the possibilities of determining the type and localization of lesions within the brain.

SUMMARY

Experiences with gamma encephalography in an unselected series of cases with cerebral disorders are reported. The changes noted in different lesions are described and related to clinical and neuroradiologic findings. It is concluded that the combined use of gamma encephalography and routine neuroradiologic procedures will increase the diagnostic possibilities.

ZUSAMMENFASSUNG

Es wird über die Erfahrungen mit der Gamma-Encephalographie in unausgewählten Fällen mit Gehirnveränderungen berichtet. Die Befunde bei verschiedenen Erkrankungen werden geschildert und mit den klinischen und neuroradiologischen Befunden in Zusammenhang gebracht. Es erscheint klar, dass die Kombination von Gamma-encephalographie und den üblichen neuroradiologischen Untersuchungsmethoden die Diagnose wesentlich erleichtern wird.

RÉSUMÉ

Présentation de l'étude gamma encéphalographique d'une série de cas tout venant d'affections cérébrales. Les auteurs décrivent les signes constatés dans diverses *lésions et les confrontent* avec les signes cliniques et neuroradiologiques. Ils concluent que l'association de la gamma encéphalographie et des examens neuroradiologiques habituels augmentera *les* possibilités du diagnostic.

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ENCEPHALOGRAPHIC CORTICAL ATROPHY

Relationships to ventricular atrophy and intellectual impairment

by

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The aims of the study have been (1) to attempt a quantitative grading of encephalographic evidence of cortical atrophy in a group of patients in whom clinical assessment indicated diffuse rather than localized brain damage (2) to investigate the relationship between this and the simultaneous ventricular findings and (3) to study the relationship between the encephalographic findings (graded quantitatively) and intellectual impairment as assessed by psychologic tests

The case material is identical to that in the preceding paper which gave an account of the radiologic and psychologic methods used These investigations as well as the recording of the results were performed concurrently without the radiologists and the psychologist being aware of each other s results

Previous investigations Important contributions to the radiologic mapping of the subarachnoid space have been made by DAVIDOFF & DYKE (1946) and LILLIEQUIST (1959) The relevant technical problems have been thoroughly

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discussed by LINDGREN (1951, 1957) and ROBERTSON (1957) It is well known that the assessment of cortical atrophy involves numerous uncertain factors, and most authors, including ENGESET (1961) and BURHENNE & DAVIES (1963), believe that it is impossible to establish exact radiologic criteria Topographic measurements have been tried by, among others, EPSTEIN & DAVIDOFF (1946) but appear to have been abandoned, according to ROBERTSON (1957) they seldom yield any information of value The time factor plays a role JIROUT (1956), for instance, found cortical atrophy to be more marked in late than in immediate films Another factor is the age of the patient ZELLWEGER (1949) and SCHAFER (1960), in particular, demonstrated that cortical sulci may be radiologically widened in children with anatomically normal brains The involution which occurs with advancing age appears to be demonstrable radiologically as early as at the age of 40 (cf LINDGREN 1954)

LILLIEQUIST's (1959) radiographic studies revealed that the subarachnoid cisterns are subject to appreciable variations The same finding was made by LINDGREN (1954) All things considered, it is dubious whether the inclusion of the cisterns in a quantitative assessment of cortical cerebral atrophy is of any value It is easier to evaluate the sulci of the convexities The present authors do not agree with BURHENNE & DAVIES (1963) that in general the width of the individual sulci cannot be determined encephalographically As mentioned in a preceding paper (NIELSEN et coll 1966), our investigation included only adults for whom we have chosen as normal width for the sulci of the convexity that given by DAVIDOFF & DYKE (1946), i e a maximum of 3 mm

Method The radiologic technique was described in our previous paper on ventricular atrophy It will merely be emphasized now that the use of fractionated insufflation is also of importance in diagnosing cortical abnormalities

In grading the cortical findings we have used only the three topographic areas of the cerebral surface where insufflation most consistently gave an acceptable degree of filling (1) the frontal, (2) the parietal, and (3) the insular regions

Individual grading of atrophy The width of each individual sulcus was graded according to the following criteria (1) under 3 mm = normal sulcus, (2) over 3, but under 5 mm = slightly widened sulcus (3) over 5 mm = greatly widened sulcus

The diagnosis of cortical air lacunae has been based upon a diameter of at least 5 mm, i e the minimal criterion of a greatly widened sulcus

Local extent of atrophy The wholly or partially air filled sulci, because of their superimposition and confluence, have not been counted Within the fron

tal parietal and insular regions no more than a simplified recording of the number of sulci has been employed This was apparently sufficient to enable important quantitative differences to be distinguished

1 All the visible sulci were normal
2 Slight widening of the sulci
3 A few i e a minority of the sulci demonstrated were greatly widened
4 Several, i e the majority of the sulci demonstrated were slightly or greatly widened
5 All the sulci demonstrated were widened slightly or greatly

Global extent of atrophy To elucidate the total extent of the cortical abnormalities the measurements of the sulci from each of the three cortical regions have been combined in the following constellations

1 *No (including doubtful) cortical atrophy* all the sulci demonstrated were normal or at most slightly widened in not more than one region

2 *Slight cortical atrophy* at most a slight widening of the sulci in at least 2 regions or at most a few greatly widened sulci, alternatively, an isolated air lacuna in at most one region and exclusively normal sulci in the others

3 *Moderate cortical atrophy* a relatively heteregenous residual group of cases which could not be classified in the better defined groups (1) (2) (4) and (5) For the actual composition of these groups see Table 2

4 *Marked cortical atrophy* greatly widened sulci measured in all three regions and several of these present in at least one of the regions, but one or more normal sulci present in all three regions

5 *Severe cortical atrophy* no normal sulci in at least one region and at the same time air lacunae and/or several greatly widened sulci in at least one region

Results

Degree and extent of cortical cerebral atrophy The findings on which the assessment of cortical atrophy has been based are given in Table 1

Sixteen of the 300 encephalograms were wholly or partially unassessable owing to deficient filling most often in the parietal region In only 3 of the encephalograms was there no air over the cortex these 3 together with 6 of the 13 cases in which the cortex was only partly assessable all had a greatly dilated ventricular system

The measurements appear to confirm the general experience that cortical atrophy is frequently most apparent in the frontal region Only every fourth frontal lobe fulfilled the requirements for encephalographic normality However it must be borne in mind and is evident from the table that although

Table 1

Individual degrees of cortical atrophy, regional distribution, and local extent of greatly widened sulci

	Width of cortical sulci					
	< 3 mm	3—5 mm	> 5 mm		Unassessable*	Total
Frontal region	71 (24 %)	40 (13 %)	186 (62 %)	47 % single sulci; 33 % several sulci; 20 % all demonstrated sulci	3 (1 %)	300 (100 %)
Parietal region	93 (31 %)	39 (13 %)	152 (51 %)	40 % single sulci; 54 % several sulci; 6 % all demonstrated sulci	16 (5 %)	300 (100 %)
Insular region	122 (41 %)	70 (23 %)	103 (34 %)	53 % single sulci; 20 % several sulci; 27 % all demonstrated sulci	5 (2 %)	300 (100 %)

* Unassessable in all three regions 3 parietal and insular regions 2 parietal region only 11 and in the frontal and insular regions only 0

greatly widened sulci are recorded in 62 % of the frontal lobes, only one in five of these cases presented such severe atrophy of all sulci demonstrated, in half the cases only a few of the sulci exceeded 5 mm in width

The air revealed varying numbers of greatly widened sulci in half the parietal lobes but it was only in a few cases that all sulci exceeded 5 mm All the sulci demonstrated were normal, i e less than 3 mm in width, in the insular region in 41 % of the cases In only one third was there a varying number of sulci of over 5 mm width as evidence of severe cortical atrophy in this region of the brain

A priori, it may seem doubtful to what extent the regional variations in cortical atrophy shown in Table 1 reflect anatomical or pathologic realities, and to what extent they are due to technical factors It should, however, be pointed out that wide sulci in one region are usually accompanied by a corresponding widening of the sulci in one or both of the other cortical regions For example, 85 % of the 152 brains with greatly widened parietal sulci showed a corresponding widening of the frontal sulci Out of the 103 brains with greatly widened insular sulci, 80 % had a corresponding parietal, and 86 % a corresponding frontal, atrophy Ninety four per cent of the 50 brains with the most severe degree of regional atrophy, i e no normal sulci (groups 5a, 5b, and 3c in Table 2), had greatly widened sulci also outside of the region concerned

Table 2

Global spread and degree of cortical atrophy

Grade	Total (%)	n
1 *No (incl doubtful) cortical atrophy*	62 (20 7)	
a) All sulci normal in all regions		47
b) Slightly widened sulci in one region sulci of all other regions normal		15
2 *Slight cortical atrophy*	60 (20 0)	
a) Slightly widened sulci in at least 2 regions without greatly widened sulci in any region		17
b) A few greatly widened sulci alternatively isolated air lacunae in one region sul i in other regions normal		43
3 *Moderate cortical atrophy*	84 (28 0)	
a) Normal sulc in all regions but with occasional greatly widened sulci in 1 region and isolated air lacunae in another region		12
b) Normal sulc in all regions but with occasional greatly widened sulci in at least 2 regions		21
c) Normal sulci in all regions but with numerous greatly widened sulci in 1 reg on a d at most slightly widened sulci in the other regions		20
d) Normal sulci in all regions but with numerous greatly widened sulci in one region and occas onal greatly widened sulci in one of the other regions		28
e) No normal ulci in one region at most a slight w den ng of sulci in the other two		3
4 *Ma ked cortical atr phy*	44 (14 7)	
a) Normal sulc in all reg ons but with a lacunae or numerous greatly widened sulci in one region and occasional greatly widened sulci in the other 2 regions		12
b) Normal sulc in all reg ons but w th numerous greatly widened sulci in one region and air lacuna(e) in another reg on		12
c) Normal sulc in all reg ons but with numerous greatly w dened sulci in at least 2 regions		20
5 *Severe cort cal tr phy*	47 (15 7)	
a) No normal ulci in one reg on and greatly w dened sulci in at least one reg on		27
b) No no m l sulci in at least 2 regions		20
Cortex ent ely unassessable	3 (1 0)	

In other words a diffuse spread of cortical atrophy is the general rule A global encephalographic pattern of greatly widened sulci must be interpreted in the selected series as indicating a more severe degree of cerebral damage than atrophy limited to one or other region

An attempt has therefore been made to grade the total brain damage in the patients according to the global extent and severity of the atrophy as demon strated regionally This arbitrary grading is presented in Table 2 in which the grouping and sub grouping reflects increasingly diffuse cortical atrophy Other grouping might be possible but the method chosen gives a certain degree of continuity and may be correlated with age ventricular atrophy, and intellec tual impairment As already mentioned group 3 i e moderate cortical

Table 3

Cortical atrophy in relation to age

	Age in years							
	18—19	20—29	30—39	40—49	50—59	60—69	> 70	Total
Cortical atrophy								
None	4	27	16	8	6	1	0	62
Slight	4	19	11	13	[illegible]	6	2	60
Moderate	1	13	9	23	15	20	3	84
Marked	0	1	3	11	14	13	2	44
Severe	0	1	0	6	16	18	6	47
Total	9	61	39	61	56	58	13	297
None to slight	89 %	75 %	69 %	35 %	19 %	12 %	15 %	41 %
Moderate to *severe*	11 %	25 %	31 %	65 %	81 %	88 %	85 %	59 %

atrophy, is a relatively heterogeneous residual group consisting of the 84 cases that could not be assigned to the better defined groups of no, slight, marked, or severe cortical atrophy

Sixty six cases of relatively localized atrophy are distributed in groups 2b, 3c, and 3e In 37 encephalograms, these regionally restricted, greatly widened sulci were frontal, in 22 cases they were parietal, and in 7 cases insular These cases are discussed below

Cortical atrophy and age Table 3 indicates that severe diffuse cortical atrophy is a very rare finding below the age of 40 years, regardless of the occurrence of *cranial injuries, birth trauma, etc (cf the diagnostic grouping in our earlier* paper) The most severe form of diffuse cortical atrophy was present in only one patient below the age of 40 years, and the marked type in only 4 such patients In contrast, only one patient over the age of 60 years had completely escaped cortical atrophy as defined in this paper

Cortical atrophy, to a greater extent than venticular atrophy, seems to be a product of the degenerative and arteriosclerotic processes of ageing, only 16 % of the patients of over 50 years of age had no, or slight, cortical atrophy In the same age group, 44 % *had a normal or only slightly dilated ventricular system* (cf Table 3 in our previous paper)

Table 4 shows the distribution of the patients with greatly widened sulci between the three age groups There is an equal distribution of widened frontal

Table 4

Regional distribution of greatly widened sulci in relation to age

	Age in years			
	18—39	40—59	> 60	Total
Sulci > 5 mm (a few several or all seen)				
Frontally	39 (21%)	87 (47%)	60 (3[illegible]%)	186 (100%)
Parietally	39 (25%)	69 (46%)	44 (29%)	152 (100%)
Insularly	6 (6%)	46 (45%)	51 (50%)	103 (100%)
Total number of assessable cases in the age groups	109 (36%)	117 (40%)	71 (24%)	297 (100%)

and parietal sulci in all the groups. Widening of insular sulci is not so frequently observed and is relatively uncommon before the age of 40 years. This seems to suggest that insular atrophy bears a closer relationship to ageing than frontal and parietal atrophy.

Cortical atrophy and the ventricular system. Table 5 demonstrates a certain correlation between cortical and ventricular atrophy. Most patients without or with only *slight cortical atrophy* have similarly either no ventricular atrophy or only a slightly dilated ventricular system. On the other hand, the size of the ventricular system varies quite capriciously in patients with marked or severe cortical atrophy, whether the size of the ventricular system is graded on the basis of the width of the third ventricle, the total width of the right and left lateral ventricles, the height of the lateral ventricles, or the combined criteria of ventricular atrophy.

The relationship between ventricular atrophy and diffuse *cortical convexity* atrophy must on the whole be considered too loose to permit the use of a demonstrated atrophy in one of these regions to serve as an indicator of atrophy of the other.

It may be added that the relatively few *encephalograms* that were only partially assessable because of incomplete filling, whether this was in the ventricular or cortical regions, have usually shown severe atrophy in the region where the findings could be assessed. The cause of the incomplete filling was presumably that, in order to spare the patients, only small quantities of air were insufflated.

Cortical atrophy and intellectual impairment. It was established in our earlier paper that the criteria of ventricular atrophy, both individually and in com

Table 5

Relation between cortical and ventricular atrophy

	Cortical atrophy						
	None	Slight	Moderate	Marked	Severe	Unassessable	Total
Ventricular atrophy							
None	30	23	23	9	8	0	93
Slight	22	17	25	11	10	0	85
Moderate	8	12	21	13	12	0	66
Severe	2	7	15	9	13	3	49
Unassessable	0	1	0	2	4	0	7
Total	62	60	81	44	47	3	300
No to slight ventricular atrophy	84 %	68 %	57 %	48 %	42 %		59 %
Moderate to severe ventricular atrophy	16	32 %	43 %	52 %	58 %		41 %

Table 6

Cortical atrophy in relation to intellectual impairment

	Cortical atrophy					
	None	Slight	Moderate	Marked	Severe	Total
Intellectual impairment						
None	26	15	13	4	0	58
Mild	31	32	34	11	5	113
Mild to moderate	4	8	17	12	6	47
Moderate	0	4	8	5	15	32
Moderate to severe	0	1	5	8	12	26
Severe	1	0	7	2	9	19
Total	62	60	84	42	47	295
No + mild impairment	92	78 %	56	36	11	58 %
> mild impairment	8 %	22 %	44	64	89 %	42

bination, show some agreement with an index of intellectual impairment, but that there is a marked scatter Fifty eight per cent of the patients had no signs of intellectual impairment or after correction for age, only mild impairment, of the remaining 42 % only a few had severe intellectual impairment The distribution is shown in Table 6 The table reveals that there is a fairly close,

Table 7

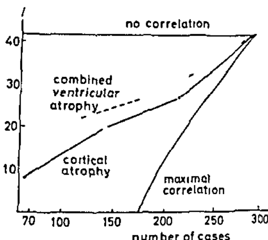
Intellectual impairment with essential discrepancy between cortical and ventricular atrophy

	Intellectual impairment						
	None	Mild	Mild moderate	Moderate	Moderate severe	Severe	Total
Marked to severe cortical/at most slight ventricular atrophy	1	10	9	8	7	2	37
Moderate to severe ventricular/at most slight cortical atrophy	2	16	6	3	1	1	29

	No + mild impairment	> mild impairment	Total
Marked to severe cortical/at most slight ventricular atrophy	11 (30 %)	26 (70 %)	37 (100 %)
Moderate to severe ventricular/at most slight cortical atrophy	18 (63 %)	11 (29 %)	29 (100 %)
		Unassessable 2	

but by no means ideal correlation between the various degrees of intellectual impairment and diffuse cortical atrophy. In all events the scatter is less marked and there is on the whole a closer agreement than was the case with ventricular atrophy. This is illustrated in the diagram now shown (p. 446) which has been produced according to the same principles as Fig. 2 in our earlier paper.

As can be seen from Table 5, in 68 (or about one quarter) of the cases there was considerable discrepancy between the degrees of cortical and ventricular atrophy, thus 39 encephalograms with evidence of marked to severe cortical atrophy presented at most a slight ventricular atrophy according to the combined measurements and 29 with moderate to severe ventricular atrophy showed at the most only slight cortical atrophy. These cases are related to the intellectual impairment in Table 7. It is evident that intellectual impairment also shows a closer correlation with cortical than with ventricular atrophy in these discrepant cases. 70 % of the cases with the more severe degrees of cortical atrophy had more than slight intellectual impairment, while this applied to only 29 % of those with appreciable ventricular atrophy.



Cumulative percentage of patients with more than mild intellectual impairment shown for the groups of ventricular and cortical atrophy calculated from $y = 100\,\frac{x - 177}{x}$ *The lines for no correlation and for maximum correlation are given for comparison*

Localized cortical atrophy Although technical artefacts cannot be excluded, 66 cases of localized cortical atrophy (groups 2b, 3c, and 3e) can be extracted from Table 2, which shows the global distribution of cortical atrophy

As mentioned in the comments on Table 2, there were very few cases (only 7) in which the atrophy was confined to the insular region The cases restricted to the frontal and parietal regions have been assembled in Table 8 where they are correlated with intellectual impairment It is evident that 10 % of the cases with apparently isolated frontal atrophy had more than mild intellectual impairment whilst this was true in only 5 % of the cases with exclusively parietal atrophy

The special correlation of intellectual impairment with frontal atrophy is confirmed when the analysis is restricted to the 43 cases in which only one cortical region (the frontal region in *23*, the parietal in *19*, and the *insular* region in one) had a few greatly widened sulci, or else an isolated air lacuna, whilst the other regions were normal (group 2b in Table 2) 10 % of the cases with frontal and none of those with parietal atrophy had more than mild intellectual impairment

This finding is taken to indicate that the localized cortical atrophies that have been demonstrated are generally not artefacts

Discussion

The vulnerable point of encephalography of the cerebral cortex is the doubtful significance of insufficient surface filling An obstructed passage, due for example to arachnoid adhesions, may be an important but is probably not a common cause A severely dilated and 'avid' ventricular system may have been responsible for a lack of cortical filling in more than half the present cases The

Table 8

Localized frontal and parietal cortical atrophy in relation to intellectual impairment

	Intellectual impairment						
	None	Mild	Mild moderate	Moderate	Moderate severe	Severe	Total
Frontal	7	15	8	6	0	1	37
Parietal	9	12	1	0	0	0	22

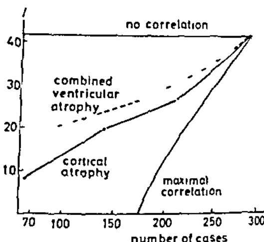
	No + mild impairment	> mild impairment	Total
Frontal	22 (60)	15 (40)	37 (100)
Parietal	21 (95)	1 (5)	22 (100)

essential feature of the present investigation is the inability to rule out the possibility that deficient filling may have masked severe atrophy or that a localized cortical atrophy may in fact have been more diffuse Conversely, localized cortical atrophy may be overlooked especially if the films are not made immediately after the insufflation and the air is trapped in the normal areas of the cortex (cf LINDGREN 1951)

Such technical uncertainties can naturally compromise the grading of cortical atrophy especially its global distribution on the convexity of the brain, and thereby the findings with regard to the relationship between cortical atrophy and intellectual impairment There is little doubt that some of the discrepancies between the radiologic and psychologic findings are due to radiologic cortical artefacts and others to imperfections in the grading of cortical atrophy On the other hand as already mentioned it would appear that it is precisely the analysis of the correlation between the regional cortical atrophies and intellectual impairment which may indicate that the localized atrophies demonstrated are not at least not generally artefacts

The clinical selection has been aimed at a series of cases that had presumably diffuse brain damage or else no organic brain damage The radiologic technique used should have led to the demonstration of localized cortical atrophy but this is not necessarily true to the same extent of localized ventricular atrophy and it is possible that this may influence the relationships between ventricular and cortical atrophy as shown in Table 5 The discrepancies could perhaps also be due to the fact that grading of the atrophy in the two areas of the brain has not been completely parallel

These and other possible reservations should not however mask the positive results that is the mutual correlation between the radiologic findings and the correlation between these as a whole and the results of the psychologic tests



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This finding is taken to indicate that the localized cortical atrophies that have been demonstrated are generally not artefacts

Discussion

The vulnerable point of encephalography of the cerebral cortex is the doubtful significance of insufficient surface filling An obstructed passage, due for example to arachnoid adhesions may be an important but is probably not a common cause A severely dilated and 'avid' ventricular system may have been responsible for a lack of cortical filling in more than half the present cases The

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COLLATERALS IN OBSTRUCTION OF THE RENAL ARTERY

by

I BROLIN and I STENER

Many reports have been published on congenital or acquired stenosis of a renal artery (e g ABESHOUSE 1941 SHEA et coll 1948 THOMPSON & SMITHWICK 1952 POUTASSE 1959) since GOLDBLATT et coll (1934) demonstrated that arterial hypertension could be induced in the dog by reduction of the blood flow to one kidney Little interest has however been focussed on studying the development of collateral pathways to the kidney in the presence of arterial obstruction HALPERN & EVANS (1962) described collateral circulation via the ureteric artery in three cases One of these had arteriosclerotic stensosis of the renal artery and the other two had what the authors termed congenital coarctation of this artery These three cases were also reported by WOODARD (1962) and the two with congenital coarctation by STEINBERG & MARSHALL (1961)

Cases with stenosis or occlusion of the renal artery or any of its branches were investigated for the occurrence of collaterals and an attempt was also being made to ascertain which arteries formed collateral circuit A preliminary report of this work has been given previously (BROLIN & STENER 1963)

Submitted for publication 30 June 1964

Some doubt was felt at the start of these investigations as to the validity of the comparisons, but it is evident that the results as a whole justify correlation of the rough data of the morphology of the brain which are furnished by the use of atmospheric air with the results of classification according to psychometric principles.

Acknowledgements

This work was aided by a grant from the Danish Science Foundation. The authors gratefully acknowledge the statistical assistance received from G. Leunbach.

SUMMARY

Encephalography was carried out in a total of 300 neurologic cases in which there was either no brain injury or presumably diffuse organic brain damage. The assessment of cortical atrophy by measuring the size of the individual sulci was restricted to the frontal, parietal and insular regions. Diffuse cortical atrophy is to a greater extent than ventricular atrophy a function of age, and it is exceptional for it to be present before the age of 40 years. There was closer correlation between intellectual impairment and cortical atrophy than between the former and ventricular atrophy, and in patients with cortical atrophy, impairment was more closely related to frontal than to parietal atrophy.

ZUSAMMENFASSUNG

Enzephalographie wurde an 300 neurologischen Fällen vorgenommen, in denen entweder keine Gehirnverletzungen oder verdächtlich diffuse organische Gehirnveränderungen vorkamen. Kortikale Atrophie konnte nur in der frontalen, parietalen und insularen Region bestimmt werden. Diffuse kortikale Atrophie ist in höherem Masse als die ventrikuläre Atrophie altersbedingt; es ist ungewöhnlich sie vor 40 Jahren anzutreffen. Es besteht eine engere Korrelation zwischen intellektueller Störung und kortikaler Atrophie als zwischen der ersterwähnten und ventrikulärer Atrophie und in Patienten mit kortikaler Atrophie wurden intellektuelle Störungen in näherem Verhältnis zur frontalen als zur parietalen Atrophie beobachtet.

RÉSUMÉ

Les auteurs ont pratiqué une encéphalographie chez 300 malades neurologiques qui ne présentaient ni traumatisme cérébral ni apparemment de lésion organique diffuse du cerveau. L'évaluation de l'atrophie corticale par la mesure des dimensions des sillons corticaux a été limitée aux régions frontale, pariétale et insulaire. L'atrophie corticale diffuse est dans une plus grande mesure que l'atrophie péri-ventriculaire fonction de l'âge et il est exceptionnel qu'elle existe avant l'âge de 40 ans. La détérioration intellectuelle est en plus étroite corrélation avec l'atrophie corticale qu'avec l'atrophie péri-ventriculaire et dans le groupe de patients présentant une atrophie corticale la détérioration intellectuelle est en corrélation plus étroite avec l'atrophie frontale qu'avec l'atrophie pariétale.

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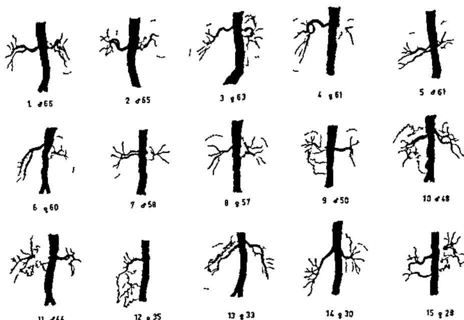


Fig 1 Schematic drawings of the nephro-angiographic findings with case numbers sex and age

Material All cases with uniform stenosis or occlusion of the renal artery or any of its main branches in the aortographic records of the department from the beginning of 1959 to the middle af 1963 were included but cases with isolated arteriosclerotic plaques were excluded Percutaneous catheterization of the aorta had always been performed and the series contained no case of selective catheterization of a renal artery

We investigated in addition 17 cases, with single kidneys or in which one kidney was silent and a normal renal artery on the same side was absent in the angiogram and 10 cases of renal tuberculosis in which the renal artery was occluded or had a markedly reduced calibre were also investigated Since no collaterals could be demonstrated in any of these 27 cases they were not included in the present case material

The material comprised 90 cases 48 men and 42 women with average ages of 52 and 53 years respectively The lesions were right sided in 33 cases left sided in 34 and bilateral in 23 cases

Results

Collateral circulation to the kidney was present in 15 of the 90 cases consisting of 7 men and 8 women the average age of the women was 46 years

Table of clinical data

Case	Sex	Age yrs	Blood pressure mm Hg	Duration of hypertension yrs	Serum creatinine mg/100 ml	Fundus hypertonicus	Microscopic diagnosis	Urography obstructed side	Index of kidney size
1	♂	66	260/120	4	1 1		Art sclerosis died	Normal	1 1
2	♂	65	200/100	5	1 7	III	Art sclerosis + nephrosclerosis	No excretion	0 6
3	♀	63	170/100	1	1 5	III—IV	Art sclerosis + pyelonephritis	Delayed excretion low density	0 6
4	♀	61	235/120	10	1 1	II—III	Art sclerosis	No excretion	0 3
5	♂	61	220/110	3	1 4	II		Delayed excretion low density	0 6
6	♀	60	210/110	6	2 7	IV	Art sclerosis died	Delayed excretion low density	0 5
7	♂	58	215/105	1	1 7	0		Delayed excretion low density	0 5
8	♀	57	220/120	1	1 8	IV		Delayed excretion low density	0 6
9	♂	50	260/140	2/12	1 8	III	Died	Delayed excretion low density	0 4
10	♂	48	215/120	1 1/2	1 6	II	Art sclerosis	Normal	1 0
11	♂	44	215/125	15	1 2	II —III	Art sclerosis + thrombosis died	Normal	1 0
12	♀	35	195/115	8	1 1	I		Normal	One kidney
13	♀	33	280/160	8	1 0	II	Fibromuscular hyperplasia died	Not performed	1 0
14	♀	30	210/130	9	1 1	I—II	Art sclerosis + pyelonephritis	Normal	0 7
15	♀	28	205/120	11	1 0	I	Aneurysm	Normal	1 1

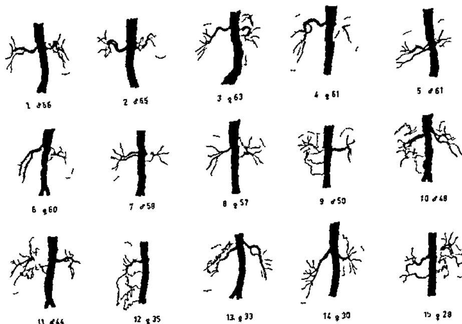


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Collateral circulation to the kidney was present in 15 of the 90 cases consisting of 7 men and 8 women, the average age of the women was 46 years



Fig 2 Case 2 Aortic nephro angiography a) Arterial and b) early nephrographic phase Occlusion of left renal artery Peripheral part of renal artery filled via short collaterals (o→) arising from the proximal part of the artery and some extremely small ones from the aorta No collaterals from the lumbar arteries The ureteric artery (→) branching from the lower polar artery is wide and possibly functions as a collateral

lower than in the material as a whole due to four of them being relatively young The clinical data in these 15 cases are given in a Table

The value given for the blood pressure represents the mean of repeated determinations before antihypertensive medication was instituted Hypertension was present in every case The data on its duration are uncertain, and the figures in the table denote the time for which it had been known, in several cases, hypertension was an incidental finding at the routine medical examination The serum creatinine was raised in about half of the cases and most cases had the fundus changes characteristic of hypertension

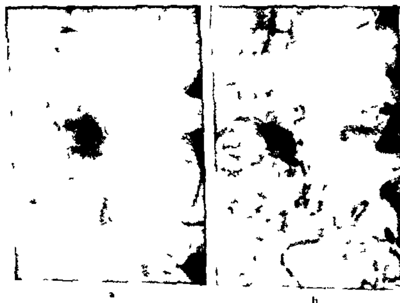
Autopsy was performed on four of the five patients who died (see Table) The microscopic diagnosis was in 6 cases based on an operative specimen and in 8 cases the histologic examination revealed arteriosclerosis Fibro muscular hyperplasia was present in one case and in another an aneurysm of the renal artery with stenosis distal to the aneurysm

Simultaneous, equal renal function on both sides was evident at urography in five cases The remaining kidney excreted normally in a nephrectomy case Six cases had delayed excretion with decreased concentration, and two had no demonstrable excretion on the stenotic side Urography was not performed in one case

The index of kidney size refers to the side with collaterals in relation to the opposite side and was obtained by measurements in the angiogram and cal



Fig 3 Case 10 Aort c nephro-angiography a) Early and b) late arterial phase in frontal view c) Ea ly arter al phase in obl que view Circula stenosis and post stenotic d latat on of right renal artery Collate als f om lumbar (→) superior capsular (⟩→) and suprarenal (⟶) arteries Aneurysmal dilat tions of right aort c wall



F g 4 Case 10 R ght kidney a) Urography D f cts in p oximal part of ureter b) Aort c neph o-a g ography (second injection and th refore fill ng of renal pel is) To tuou c llate als at site of defects



Fig 3 Case 11 Aortic nephro angiography Right renal artery occluded a few millimetres from its origin (⟜) *its branches are filled via wide* tortuous collaterals from the inferior phrenic (→) and lumbar (->) arteries The collaterals communicate with the renal artery at the site of branching and with the *lower polar* artery Arteriosclerotic plaque in left renal artery Arterial phase (b) two seconds after (a)

culation of the size according to MOELL (1961) All four cases in which urography disclosed a kidney of normal size on the side with collaterals had normal excretion

A schematic representation of the angiographic findings in the 15 cases with collaterals is given in Fig 1 Five cases had collaterals on the right and ten on the left side Occlusion of the renal artery was present in nine cases (Cases 2 to 9 and Case 11) and marked stenosis in four (Cases 1, 10, 12 and 14) In one (Case 13), the ventral main branch was occluded, and in one (Case 15) there was an aneurysm of the renal artery with marked stenosis peripheral to it The left kidney in Case 12 had been removed on the grounds of secondary hydronephrosis following operation for a double ureter with an ectopic orifice Four cases (Cases 2, 3, 13 and 14) had a normal renal artery on the contralateral side but in the other ten cases more or less severe stenosis of the renal artery was present on the other side as well The outlines of the abdominal aorta were regular in four cases (Cases 2, 12, 13 and 15) while in the others varying degrees of arteriosclerosis, ranging from isolated plaques to confluent mural lesions with aneurysmal dilatation, were evident



Fig 6 Case 13 Aortic nephro-angiography (right kidney) Occlusion of ventral branch of renal artery Two k of collaterals from suprarenal (→) and inferior phrenic (→) arteries with delayed filling of peripheral part of ventral branch (⟶) Arterial phase (b) two seconds after (a)

Collaterals were present both cranial and caudal to the origin of the renal artery in ten cases being caudal only in one (Case 12) and cranial only in three (Cases 1 5 and 13) The contrast medium had been injected into the aorta so far distally in Case 15 that it was not obvious whether or not there were collaterals above the renal artery

Illustrative case reports

Male aged 60 (*Case 2*) with a 5-year history of hypertension no renal disease Normal findings on the right side at urography slightly smaller kidney and no *excretion on the left side*

Aortic nephro-angiography (Fig 2) Occlusion of the left renal artery 1 cm from its origin from the aorta for a distance of about 1 cm the peripheral part of the renal artery was filled after about 1 second via a just over 1 mm wide *cranial collateral* and some fine-calibered short collaterals caudal to the occlusion normal nephrographic effect

Nephrectomy was performed inappreciable pulsations in the distal part of the renal artery Microscopy revealed arteriosclerosis + nephrosclerosis



a b

Fig. 5. Case 11. Aortic nephro-angiography. Right renal artery occluded a few millimetres from its origin (o→); its branches are filled via wide, tortuous collaterals from the inferior phrenic (→) and lumbar (➤) arteries. The collaterals communicate with the renal artery at the site of branching and with the lower polar artery. Arteriosclerotic plaque in left renal artery. Arterial phase (b) two seconds after (a).

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A schematic representation of the angiographic findings in the 15 cases with collaterals is given in Fig. 1. Five cases had collaterals on the right and ten on the left side. Occlusion of the renal artery was present in nine cases (Cases 2 to 9 and Case 11) and marked stenosis in four (Cases 1, 10, 12 and 14). In one (Case 13), the ventral main branch was occluded, and in one (Case 15), there was an aneurysm of the renal artery with marked stenosis peripheral to it. The left kidney in Case 12 had been removed on the grounds of secondary hydronephrosis following operation for a double ureter with an ectopic orifice. Four cases (Cases 2, 3, 13 and 14) had a normal renal artery on the contralateral side but in the other ten cases more or less severe stenosis of the renal artery was present on the other side as well. The outlines of the abdominal aorta were regular in four cases (Cases 2, 12, 13 and 15) while in the others varying degrees of arteriosclerosis, ranging from isolated plaques to confluent mural lesions with aneurysmal dilatation, were evident.



Fig 8 Case 15 Arteriogram of specimen (left kidney) All branches of the renal artery were filled from needle at site of branching and found to be of normal width Leakage of medium from lower polar branch

the right renal artery was occluded its branches being filled in a peripheral direction after 1 to 2 seconds via wide collaterals which included the inferior phrenic lumbar and capsular arteries Collaterals also communicated with the peripheral part of the lower polar artery Normal nephrographic effect Arteriosclerotic plaque at the site of branching of the left renal artery

At autopsy obliteration of the middle part of right artery with mural thrombus proximally Two tortuous arteries given off from the aorta caudal to the renal artery could be traced to the hilum of the kidney Several other collateral vessels were present but they were so fine and thin walled that they could not be identified Microscopy arteriosclerosis + thrombosis

Female aged 33 (*Case 13*) with a 8 year history of hypertension no renal disease who died of cerebral haemorrhage Urography was not performed

Aortic nephro-angiography (Fig 6) Occlusion of the ventral branch of the right renal artery 0 5 cm peripheral to its branching The peripheral part of this branch was filled via a network of collaterals from the suprarenal and inferior phrenic arteries Normal nephrographic effect No changes were demonstrable in the aorta and left renal artery

At autopsy isolated atheromatous plaques were found in the abdominal aorta obliteration of the ventral branch of the right renal artery Microscopy fibro-muscular hyperplasia

Female aged 28 (*Case 15*) with a 11 year history of hypertension no renal disease Normal findings at urography

Aortic nephro-angiography (Fig 7) No filling of the main trunk of the left renal artery A rich network of collaterals were given off from the lumbar arteries one of which had an aneurysm close to its origin at the aorta The collaterals were in communication with the lower polar artery and with the renal artery in the hilum of the kidney Since the former collateral communication was most strongly developed the peripheral part of the lower polar artery was filled earlier and better than other branches of the renal artery Slight homogeneous filling of a

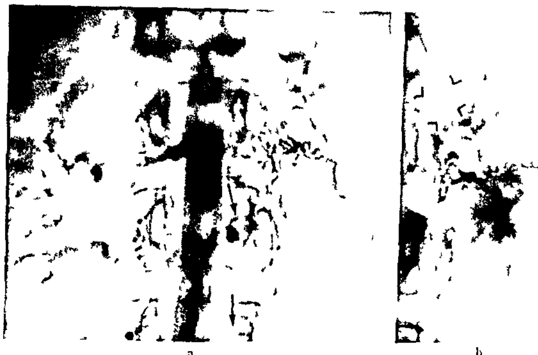


Fig 7 Case 15 Aortic nephro angiography No main renal artery to left kidney visible Rapid filling of lower polar branch and delayed filling of other branches via wide tortuous collaterals from lumbar arteries (→) one of which has an aneurysm Homogeneously filled area (>) found at operation to be an aneurysm of the main renal artery Lower polar artery to right kidney duplicated Arterial phase (b) two seconds after (a)

Male aged 48 (*Case 10*) with a 18 month history of hypertension He had had attacks of renal colic at 27 and 44 years of age Urography was normal with the exception of small defects in the proximal part of the right ureter

Aortic nephro angiography (Fig 3) Aortosclerosis with aneurysmal dilatations marked uniform stenosis of the right renal artery at its origin from the aorta post stenotic dilatation *Collaterals from the lumbar arteries both cranial and caudal to the renal artery in addition* collateral circulation via an artery arising from the aorta 1 cm caudal to the renal artery The latter artery divided into a superior capsular artery and a thicker caudal branch to *produce an anastomosis to collateral branches from the lumbar arteries* The collaterals formed a close network in the lower part of the hilum of the kidney and communicated with the lower polar artery This network corresponded to the site of the defects in the right ureter observed at urography (Fig 4) *Normal nephrographic effect* Double left renal arteries with small arteriosclerotic plaques

Operation with new implantation of the right renal artery was performed difficulty was found in chilling the kidney with cold plasma Microscopy arteriosclerosis

Male aged 44 (*Case 11*) with a 15 year history of hypertension who died following myocardial infarction one week after angiography Normal findings at urography except for small defects in the medial *wall of the right renal pelvis* and *proximal part of the right ureter* (These changes had been present 7 years before but were then less distinct)

Aortic nephro angiography (Fig 5) Sclerosis of abdominal aorta The whole main trunk of

Even normally good communication exists between the different vascular regions of the ureter (LICH & HOWERTON 1963)

Because of the great variations in the extrarenal branches of the renal artery — the middle capsular and ureteric arteries may for example arise from the same branch — as well as because of the changes in relative calibre associated with development of a collateral circuit it is not always possible to determine exactly which vessels act as collaterals

The vessels arising proximal to the stenosis could be identified in most of the present cases but those arising distal to it in only a few of them Vessels given off from the aorta always partook in the collateral circulation as did vessels given off from the renal artery proximal to the stenosis in Cases 2 and 12 (Figs 1 and 2) The vessels given off from the aorta consisted of lumbar arteries in Cases 3 6 to 9 12, 14 and 15 (Figs 1 and 7) of lumbar arteries and suprarenal arteries in Cases 10 and 11 (Figs 1, 3 and 5) and of suprarenal arteries only in Case 13 (Figs 1 and 6) Identifiable vessels arising distal to the stenosis consisted of suprarenal arteries in Cases 10 11 and 13 (Figs 1 3 5 and 6) of superior capsular artery in Case 10 (Figs 1 and 3) and of the ureteric and/or other capsular arteries in Cases 3 10 to 12 and Case 15 (Figs 1, 3 5 and 7)

HYRTL (1872) described peripheral branches of the renal artery which perforated the surface of the kidney BOIJSEN (1959) observed such perforating arteries in a few small kidneys with a narrow renal artery Arteries of this type were evident in Cases 3 12 and 14 of the present material (Fig 1)

The inferior capsular artery generally arises from the internal spermatic artery and anastomoses with the superior capsular artery This anastomosis was described by SCHMERBER (1896) as l arcade artérielle exorénale A possibility therefore exists of the development of collaterals from the internal spermatic artery this was not observed in the present series

Few cases of collateral circulation to the kidneys have been described in the literature A possible explanation is that the collaterals were misinterpreted as vascular malformations ISAAC et coll (1957) reported a case in which the renal artery was replaced with several vessels of small calibre They emphasized that these arteries did not have the appearances of a well defined cirsoid angioma it may be presumed they consisted of collaterals developed secondarily to an arterial obstruction In the two cases which they described as congenital malformations in the form of cirsoid angioma it can be questioned whether the tortuous vessels were not in fact acquired collaterals When the angiographic examination was made these two patients were 25 and 24 years old and had histories of hypertension for 8 and 5 years respectively

KARANI et coll (1962) reported a case of a 27 year old man with a malformation of the renal artery of the cirsoid angioma type They also suspected

vascular sac about 2 cm in diameter, medial and cranial to the hilum of the kidney was evident *in the late arterial phase* (Fig 7b) Normal nephrographic effect The right renal artery was duplicated, both these vessels and the aorta presented no obvious changes

Left nephrectomy was performed which revealed a walnut sized aneurysm of the renal artery which was extremely narrow peripheral to it (data on the appearance of the central part of the artery are lacking) A number of small arteries ran towards the hilum of the kidney

Arteriography of specimen (Fig 8) All branches of the renal artery filled through a needle introduced to the site of branching were normal in width Leakage of contrast medium took place from the lower polar artery

Discussion

It is apparent from the present *material that a collateral* circulation may be developed via a number of different arteries in stenosis or occlusion of the renal artery This takes place by an extension of normally existing communications between, on the one hand, vessels arising from the aorta or the renal artery proximal to the obstruction and, on the other hand, vessels given off *from the renal artery or any of its branches distal to the obstruction* The flow in the latter vessels will be in a retrograde direction Communications that can be developed are present in the adrenal gland, renal capsule and ureter, the vascular supply of which is subject to great variations, this fact, together with the site of the obstruction, may explain the differing appearances of the collateral system from case to case

Development of a collateral system via the *adrenal gland* is possible in those cases in which the inferior phrenic and/or the superior suprarenal artery arise from the aorta or renal artery proximal to the obstruction, and an inferior suprarenal artery is given off distal to it The inferior phrenic and superior suprarenal arteries generally arise from the aorta, and more infrequently from the proximal part of the renal artery, the occurrence of an inferior suprarenal artery arising from the renal artery or one of its branches is inconstant (BOIJSEN 1959)

A collateral circuit may develop via the *renal capsule* due to the fact that capsular arteries are given off from lumbar arteries, as well as from the renal artery or its branches There is a great variation in the occurrence of branches to the renal capsule from the renal artery The middle capsular artery which arises either from the renal artery or from one of its main branches, usually the dorsal artery (BOIJSEN), is the most constant

Development of a collateral circuit via the *ureter* may take place owing to the proximal part of the ureter (like the renal pelvis) being supplied by the renal artery, and its central part by lumbar arteries The proximal part of the ureter generally receives a branch from the lower polar artery and the renal pelvis several small branches from the distal part of the renal artery (BOIJSEN)

of the present material This figure is a minimum value since extremely fine calibred collaterals cannot be demonstrated with our current angiographic technique A prerequisite for depiction of all collaterals is for the contrast medium to be injected into the aorta and not selectively into the renal artery Injection of the medium into the aorta does however often imply filling of the superior mesenteric artery and its branches which in certain cases makes it impossible to decide whether or not collateral vessels are present

SUMMARY

An account is given of 15 cases with development of a collateral circulation to the kidney in stenosis or occlusion of the renal artery studied by aortic nephro-angiography The occurrence of collaterals is found to be relatively common The prerequisites for the collaterals are discussed and it is stressed that for their demonstration the contrast medium must be injected into the aorta and not selectively into the renal artery

ZUSAMMENFASSUNG

Funfzehn Falle mit Ausbildung eines Kollateralkreislaufes der Niere nach Verengung oder Blockierung der Nierenarterie wurden mittels aortaler Angiographie untersucht Die Ausbildung eines Kollateralkreislaufes ist relativ haufig Die Bedingungen fur die Entwicklung eines solchen Kollateralkreislaufes werden beschrieben und es wird betont dass zur Aufzeigung dieses Kreislaufes das Kontrastmittel in die Aorta eingespritzt werden muss und nicht selektiv in die Nierenarterie

RÉSUMÉ

Présentation de 15 cas de sténose ou d obstruction de l artere rénale dans lesquels s est développé une circulation collatérale destinée au rein et étudiée par néphro-angiographie aortique L apparition de collatérales parait relativement fréquente Les auteurs étudient les conditions anatomiques indispensables au développement de collatérales Ils soulignent que pour mettre en évidence les vaisseaux collatéraux il faut injecter le moyen de contraste dans l aorte et non électivement dans l artère rénale

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the presence of an arteriovenous fistula between the angioma and the inferior vena cava. Although their illustrations do not permit any detailed analysis, it seems likely that secondary collaterals could offer the most probable explanation. The vessel interpreted as the inferior vena cava might have been the superior mesenteric artery.

The collaterals in Cases 11, 13 and 15 were so extensively developed that they in some respects suggested a cirsoid angioma (Figs. 1, 5, 6 and 7). When hypertension was diagnosed, these patients were 29, 25 and 17 years old, respectively, it was thus a matter of young patients in whom there is a greater likelihood of development of an extensive collateral system than in older subjects. This is borne out in the present series by the fact that all but one of the patients over 50 years of age had only small, short collaterals (Fig. 1, Cases 1, 2 and 4 to 8).

HOWARD et coll. (1954), in reporting a case in which no normal renal artery was found at microscopic examination of the excised kidney, stated "... in the hilum of the kidney a number of small renal arteries entered the kidney but the main artery was not present". It would appear to the present writers that these small arteries may have been collaterals. The same observation, i.e. a number of small arteries running towards the hilum of the kidney, was made at operation in Case 15 (Fig. 7). It cannot be determined whether or not the aneurysm in this case was based on a congenital malformation. Irrespective of the origin, it would seem probable that the tortuous arteries, demonstrated by angiography and observed by the surgeon, consisted of collaterals.

The difficulty of chilling the kidney with cold plasma during operation in Case 10 must presumably be ascribed to the well developed collateral circulation.

Despite occlusion of the renal artery, such a good collateral circulation may be formed that roentgenologically the kidney has a completely normal size and function (Case 11).

ISAAC et coll. (1957), HALPERN & EVANS (1962) and WOODARD (1962) have pointed out that urography may suggest a vascular malformation if typical defects in the renal pelvis and upper part of the ureter are demonstrable. Such defects were evident in Case 10 (Fig. 4) and Case 11. In other cases, in which the roentgenograms could be evaluated from this angle, no deformation of the renal pelvis or ureter could be demonstrated. This may be explained by the fact that the collateral vessels were sometimes of such a small calibre or ran such a course that they could not be traced.

The present analysis of aortic nephro angiograms in cases of stenosis or occlusion of the renal artery or its branches shows that a collateral circulation to the kidney is relatively common. It was present in 17 per cent of the cases

of the present material This figure is a minimum value since extremely fine calibred collaterals cannot be demonstrated with our current angiographic technique A prerequisite for depiction of all collaterals is for the contrast medium to be injected into the aorta and not selectively into the renal artery Injection of the medium into the aorta does however often imply filling of the superior mesenteric artery and its branches which in certain cases makes it impossible to decide whether or not collateral vessels are present

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DETERMINATION OF OPTIMUM FILM DENSITY RANGE FOR ROENTGENOGRAMS FROM VISUAL EFFECTS

by

HITOSHI KANAMORI

Several investigations have been published on the optimum film density of roentgenograms for the perception of change in thickness or composition of objects as well as on the density range when the thickness or composition changes over a wide range The density values have been derived by experience, i e by measuring the density of good roentgenograms An appreciation of the physics of optimum values would appear to be essential in determining the quality control and automation standards required

The existence of optimum values will be explained on the basis of visual effects used in optics and illumination engineering A roentgenogram should possess uniformly acceptable physiologic contrast i e film contrast (gamma) modified by visual effects and sharpness The latter will not be considered in this paper

Minimum perceptible contrast in roentgenograms MOON & SPENCER (1945, 1948) gave the following empirical equation of minimum perceptible bright

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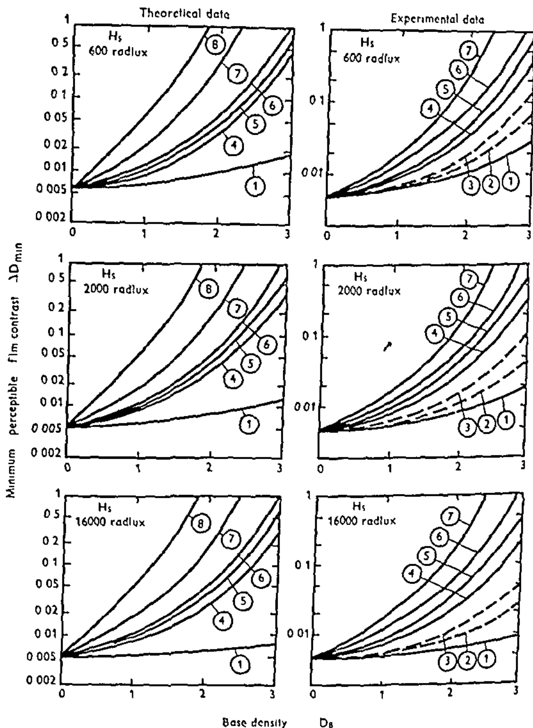


Fig. 1. Relationship of minimum perceptible contrast to base density for three values of brightness of film viewer.

Table 1

Curve number data of fig. 1

Curve number	Visual angle in rad	Diameter of films in cm at 25 cm eye distance
1	2 (whole field)	∞
4	0.050	2.5
5	0.030	1.5
6	0.0262	0.655
7	0.0131	0.328
8	→ 0	→ 0

ness contrast c_m of non-uniform surroundings under steady state adaptation, i.e. when the eyes are fixed on a test piece

$$c_m = \frac{(H_B - H_O)_{mi}}{H_B} = \frac{0.0123}{H_B}\,(0.808+\sqrt{H_A})^2 \quad H_A \geqslant H_B \tag{1}$$

where H_O, H_B and H_A are helios (brightness) of a test piece, helios of the region around the test piece and adaptation helios respectively. MOON & SPENCER deduced this equation from their own and from the summation of other work on the brightness of lamps, luminaries, light diffusing surfaces, illuminated surfaces in illumination engineering and optics, but not with reference to roentgenograms. They also pointed out that adaptation helios of non-uniform surroundings may be calculated from the HOLLADAY principle (1926) and its modifications as reported by STILES & CRAWFORD (1929).

The term contrast as mentioned above is the ratio brightness change/base brightness $(H_B - H_O)/H_B$ while the contrast in roentgenograms is the change in film density including logarithmic notation as expressed in equation (2). Assuming that a roentgenogram is examined in a film viewer, we let H_B, H_O and H_S represent the brightness of the film densities D_B, D_O and of the viewer respectively, and obtain

$$\left.\begin{aligned} D_B &= \log H_S - \log H_B \\ D_O &= \log H_S - \log H_O \end{aligned}\right\} \tag{2}$$

In the remainder of this paper the term contrast is used to denote the change in film density in a roentgenogram.

Using eqs (1) and (2) we obtain the minimum perceptible contrast ΔD_{mi} of a roentgenogram

$$\Delta D_{mi} = (D_B - D_O)_{mi} = \log\left[1 - \frac{0.0123\,(0.808+\sqrt{H_A})^2}{H_S\ 10^{-D_B}}\right] \tag{3}$$

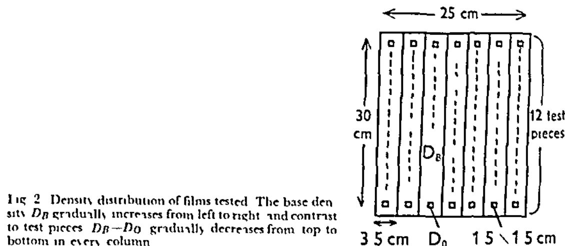


Fig. 2. Density distribution of films tested. The base density D_B gradually increases from left to right and contrast to test pieces $D_B - D_O$ gradually decreases from top to bottom in every column.

From the last equation it follows that the minimum perceptible contrast is a function of H_S, H_A, and D_B. The theoretical ΔD_{min} to base density D_B for three values of H_S, are shown on the left in Fig. 1. H_S is expressed in radlux (≡ blondel), and the curve numbers relate to adaptation helios and are therefore related to the film size, as shown in Table 1. In the second column of the table, the visual angles of the film are given, and in the third column the diameter of the films at an eye distance of 25 cm. The film size decreases with the curve number. Curves 2 and 3 were used only experimentally and are not included in Table 1.

The factors of film viewers used are shown in Table 2, and the density distribution of the films tested are given in Fig. 2. The base density D_B gradually increases from left to right and the contrast, $D_B - D_0$ gradually decreases from top to bottom in every column in Fig. 2. The density was measured with a microphotometer.

It was feared that such a small contrast as 0.005 could not be measured

Table 2

Factors of viewers used in the experiments

Viewer brightness in radlux	Light source	Size in cm²
600	Tungsten lamp	28.0 × 39.0
1 800	Fluorescent lamp	28.6 × 39.0
15 500	Fluorescent lamp	41 × 11

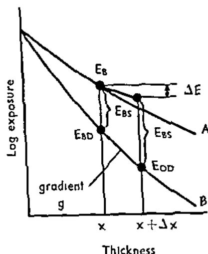


Fig 3 Graphical illustration of calculation of change in exposure ΔE from absorption curves curves A and B show measured values including scattered rays and those of direct rays alone respectively Since the test piece area is small total rays behind the test piece may be the sum of direct rays behind the test piece E_{OD} and scattered rays from the base phantom around the test piece E_{BS}

accurately The measurement results were therefore compared with the values calculated from absorption curves by using the following equation

$$\Delta D - \gamma \log \frac{E_B}{E_{BS} + E_{BD}\ 10^{-g\Delta}} \tag{4}$$

where γ is the gradient of density exposure curves corresponding to the base density D_B which can be measured with a microphotometer and the logarithm is the change in exposure ΔE constituted from the thickness Δx of the test piece

The change ΔE is illustrated in Fig 3 Curve A is obtained experimentally with the same factors of kV mA screen field size position of objects as when test films were made Curve A therefore represents values including scattered rays in addition to direct rays whereas curve B includes only direct rays Direct rays are measured by the method of TROUT et coll (1960)

Let E_{BS} E_{BD} and E_{OD} be the exposure due to scattered rays at x, direct rays at x and direct rays at $x + \Delta x$ respectively then the total exposures at x and $x + \Delta x$ are probably $E_{BS} + E_{BD}$ ($= E_B$) and $E_{OD} + E_{BS}$ respectively

For small Δx E_{OD} should be obtained by using the gradient g of curve B at x as

$$\log E_{OD} - \log E_{BD} = -g\Delta x \quad \text{that is} \quad E_{OD} = E_{BD}\ 10^{-g\Delta} \quad \text{obtaining eq 4}$$

It was confirmed that the calculated values coincided with the microphotometrically measured values within permissible experimental errors and there

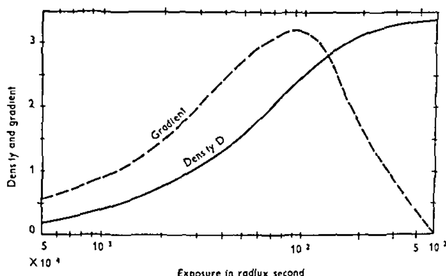


Fig. 1 Density exposure characteristics of a typical emulsion FUJI PX and its gradient. Since radlux is a unit of all visible rays except ultraviolet the abscissa is a relative value of exposure.

fore the measured values were used. Scattered rays were utilized for reducing contrast in the test films. Since scattered rays may in practice be removed, only direct rays will be considered below.

Several films, having the same shapes as the film in Fig. 2, were inspected with respect to curve numbers for obtaining data of various adaptation helios.

Curve 1. The entire film was first bordered with black paper, and secondly only test pieces were covered. The values obtained were identical. This curve corresponds to curve 1 of the theoretical data.

Curve 2. The film was cut into equal density strips, 25 mm wide and arranged in columns, 25 mm apart.

Curve 3. One strip was placed in the center of a film viewer. Because of the complex density distribution, curves 2 and 3 represent diagnostic roentgenograms.

Curves 4 to 7. Every test piece was so separated that it included a region with base density of the diameter indicated in the third column of Table 1, and then it was placed in the center of a film viewer.

About twenty observers, including roentgen technicians, judged the contrasts. Inspection was conducted in a darkened room to eliminate reflected light from the film surface. The eyes were focussed on a test piece until 'steady state adaptation' prevailed. Adequate rest was taken by the observers between inspections so that *their eyes would recover from glare conditions.* This was

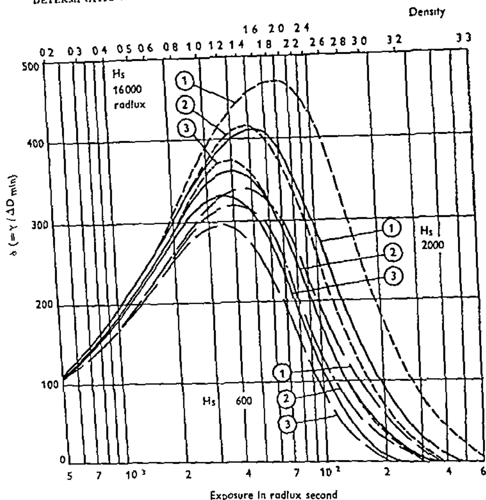


Fig 5 Physiologically modified gamma $\delta (= \gamma / \Delta D_m)$ The density at each maximal δ is the most perceptible or the optimum density for each factor

important when high density films of small size were inspected Threshold contrast values ΔD_{min} were thus plotted and smoothed into curves

The experimental results thus obtained are shown on the right in Fig 1 Theoretical and experimental curves of the same number agree within permissible experimental errors in Fig 1 MOON & SPENCER s empirical equation can therefore be applied to roentgenograms It follows from Fig 1 that contrast is more easily perceptible with increase in brightness of a film viewer, decrease in base density and increased uniformity in density distribution The

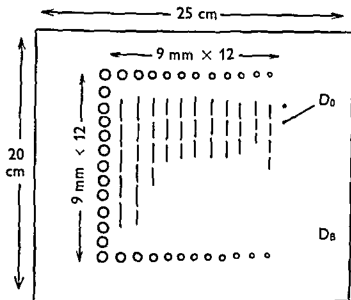


Fig 6 Density distribution of films tested for small test pieces Diameters of test piece area are equal in each column and decrease from left to right from 7 mm to 1 mm at 0.5 mm intervals Contrast gradually decreases from top to bottom in every column

glare due to the low density parts of a film in the visual field results in poor perceptibility of the high density parts It may also be concluded from Fig 1 that an optimum density does not exist if the effect of change in object thickness is not considered Under ideal conditions a contrast of 0 005 is perceptible

Experimental data from 2 000 radlux will be used as representative of diagnostic roentgenograms because the brightness of the film viewers usually used in roentgen diagnosis is from 1 500 to 3 000 radlux

Physiologic contrast and optimum density Contrast, in the physical sense, ΔD, constituted by a change in thickness Δx is expressed $\Delta D = \gamma g \Delta x$ (5) where g is the gradient of a radiation absorption curve (thickness to film exposure curve) and γ is that of a density to exposure curve, where exposures are in logarithmic scale

Now, the physiologic contrast, S, may be defined as

$$\Delta S = \Delta D / \Delta D \qquad (6)$$

from which the contrast having the same ΔS may be distinguished with identical perceptibility By the substitution of eq (5) in (6) we obtain

$$\Delta S = g \delta \Delta x \qquad (7)$$

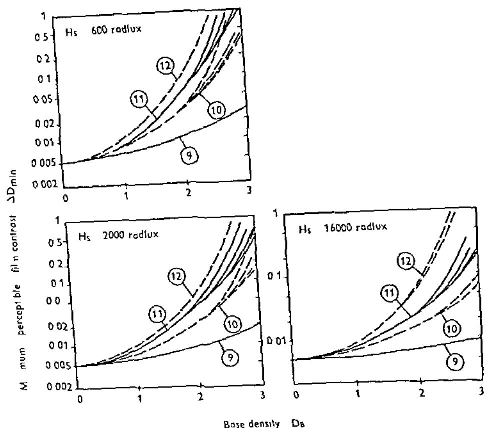


Fig 7 Minimum perceptible contrast in small test pieces The diverging curves correspond to test pieces with diameters from right to left of 1 3 5 and 7 mm in curves 10 and 11 and of 1 and 3 mm in curve 12

$$\text{where } \delta = \gamma / \Delta D_{mi} \tag{8}$$

i e δ means physiologically modified γ Provided that an absorption curve is a straight line i e g is constant δ results in relative physiologic contrast A larger δ results in easier perceptibility

As examples of the calculation of δ the gradient γ of a typical film FUJI PX (Fig 4) was used It is shown that γ reaches a maximum at density 2 5 If visual effects are not considered thus 2 5 is the optimum density

A number of the calculated δ are plotted in Fig 5 the experimental ΔD_{mi} were used for these calculations

The curve numbers in Fig 5 correspond to those in Fig 1 Every curve takes

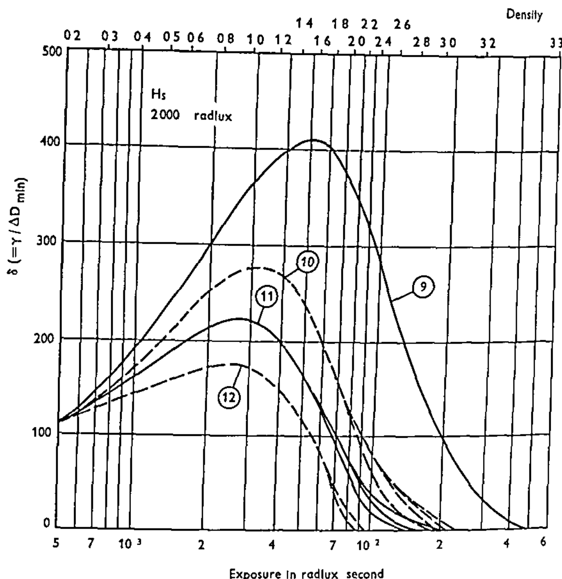


Fig 8 Physiologically modified gamma δ of small test pieces The diverging curves correspond to test piece diameters from left to right of 1 3 5 and 7 mm in curves 10 and 11 and of 1 and 3 mm in lower curve 12

a maximum of δ, and its corresponding upper abscissa is the most perceptible density, i e the optimum density From the curves 3, 2, and 1, for 2 000 radlux, the optimum densities, all less than the 2 5 mentioned above are 1 26, 1 3, and 1 6, respectively The corresponding ΔD_{min}, as derived from Fig 1, are 0 0068, 0 0066 and 0 0058 The values derived from 3 and 2, corresponding to diagnosis, are more readily perceptible than the experiential values of 1 0 and 0 02, which were reported by FUJIMOTO (1944) and cited by KOYANAGI

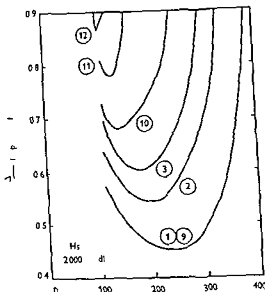


Fig 9 Minimum perceptible percentage thickness change $\Delta x/x$ calculated from δ-curves in figs 5 and 8 with eq (12)

(1959) and SHAAR (1960) This difference may be caused by using a larger test piece area than that of clinical roentgenograms

Generally speaking film density is more uniform and film viewers are brighter in industrial than in diagnostic roentgenograms It is considered by experience from industry that the optimum density is 1 5 or more (McMASTER 1959) Curve 1 of $H_S = 2\,000$ 16 000 corresponding to industrial cases may serve to explain these experiential values

Small test pieces Since diagnostic roentgenograms require that change in thickness of a small area be perceptible test pieces smaller than those described in the previous sections should be used Films of the shape shown in Fig 6 were therefore employed these are roentgenograms of a Loch Phantom The diameters of the test pieces are equal in each column and decrease from left to right from 7 mm to 1 mm at 0 5 mm intervals The contrast decreases gradually from top to bottom in every column More than 20 films with several base densities between 0 2 and 3 4 were prepared They were inspected as follows with respect to curve numbers for various adaptation helios

Curve 9 Procedures and results were the same as for curve 1

Curve 10 Each column was so separated that test pieces of the same diameter were arranged in one strip Three strips were laterally connected at the center of a film viewer It was noted that the middle strip was more perceptible than the others Contrast in this strip was tested

Table 3

Optimum density ranges and corresponding $\Delta x/x$ calculated from the data of the 2 000 radlux viewer in figs 5 and 8

Curve number	Optimum density range	$\frac{\Delta x}{x}$ in %
1 9	0 54 ~ 2 6	0 45
2	0 4 ~ 2 41	0 55
3	0 4 ~ 2 15	0 60
10	0 28 ~ 2 05	0 68
11	0 27 ~ 1 75	0 78
12	0 2 ~ 1 6	0 87

Curve 11 First, some of the strips were arranged in columns at 1 cm intervals, and, second, only one of the strips was placed at the center Both showed the same results The former may be nearly equivalent to che t diagnoses

Curve 12 The columns with test piece diameters of 1 mm to 3 mm were cut into 4 mm wide strips and tested

Other conditions were the same as with the large test pieces The experimental results of ΔD_{min} are plotted in Fig 7, from which it follows

1 *A lower contrast may be distinguished with a brighter viewer and lower* film density

2 If the density distribution is uniform, minimum perceptible contrast is *independent of the size of the test piece*

3 If the density distribution is not uniform, low contrast is hardly perceptible because of the effects of glare due to the low density parts of the film *In this case, with the larger D_n, the smaller test pieces are hardly perceptible*

Fig 8 shows δ for 2 000 radlux, derived from Fig 7 Optimum densities of 1 1, 1 0, and 0 9, respectively, are obtained from curves 10, 11 and 12 The experiential value 1 0 *is thus confirmed*

Optimum density range If the contrast, ΔD, due to thickness change, Δx, is larger than the minimum perceptible contrast ΔD_{min}, we obtain eq (9) from eqs (6) and (7)

$$\text{thus } \delta g \Delta x \geqslant 1 \tag{9}$$

Assuming that an absorption curve is a straight line, we put

$$g = (1/x)\ (\log E_2 - \log E_1) \tag{10}$$

Then the density range in which Δx can be distinguished must be obtained from the next equation

$$(\log E_2 - \log E_1) \geqslant x/\Delta x \qquad (11)$$

where, $x = x_1 - x_2$ and (E_1, E_2) is the film exposure range corresponding to the ends of the thickness range $(x_1\ x_2)$ of an absorption curve The corresponding density range $(D_1\ D_2)$ can be obtained from Fig 4

We now must consider the perceptibility at both ends of the range where it is lowest

Let δ_0 Δx_0 be the values of δ, Δx at the ends of the range respectively then

$$\delta_0 (\log E_2 - \log E_1) = x/\Delta x_0 \qquad (12)$$

The right side is the reciprocal ratio of perceptible thickness change Δx_0 to thickness range x corresponding to the range $(D_1\ D_2)$

Relations between $\Delta x_0/x$ and δ_0 calculated from the curves for 2 000 radlux in Fig 5 and Fig 8 are shown in Fig 9 Every curve in the figure has a minimum of $\Delta x_0/x$ to δ_0 since the left part of eq (12) has a maximum due to the curve shapes

The discovery of the minima formed the essential basis of this communication If δ_0 be so selected that $\Delta x_0/x$ reaches a minimum a change in thickness of the object is most perceptible near both ends If δ_0 is larger, x decreases and $\Delta x_0/x$ therefore increases This results in a decrease in perceptibility not only at the ends of the range but also over the entire range $(D_1\ D_2)$ If on the other hand δ_0 is smaller the perceptibility decreases at both ends Δx_0 increases and $\Delta x_0/x$ therefore increases If therefore a δ curve intersects with its optimum δ_0 level the limited range of abscissa corresponds to the optimum density range The range calculated from the curves for 2 000 radlux in Fig 5 and Fig 8 and the corresponding $\Delta x_0/x$ are shown in Table 3 The range becomes narrower and the change in thickness becomes less perceptible with decreasing uniformity in density Industrial roentgenograms therefore have a wider range than diagnostic roentgenograms

The range obtained from curves 11 and 12 which correspond to chest roentgenograms agrees with several experimental results i e the density range of good roentgenograms selected by physicians The optimum density range for other objects or other inspection factors could be found by the same process

Acknowledgements

The author wishes to express his gratitude for the great help received from Prof Yasuyuki Otani and Prof Tadao Sakaguchi of Kyoto University

SUMMARY

Basic calculations for obtaining optimum film density and contrast are presented and the factors involved in the production of an acceptable roentgenogram are discussed. Minimum perceptible contrast of roentgenograms was calculated from an empirical formula utilized in optics and illumination engineering.

ZUSAMMENFASSUNG

Die Grundlagen für das Erreichen bester Filmdichte und hochsten Kontrastes werden erörtert und die Faktoren, die zu guten Röntgenaufnahmen führen, werden besprochen. Minimal wahrnehmbarer Kontrast von Röntgenbildern wurde nach einer empirisch gefundenen Formel bestimmt; diese Formel wird in der Optik und Beleuchtungstechnik allgemein verwendet.

RÉSUMÉ

L'auteur a déterminé l'optimum de densité et de contraste des films roentgen et examine les facteurs qui interviennent dans la production d'une radiographie acceptable. Il a calculé le contraste perceptible minimum des radiographies d'après une formule empirique utilisée en optique et en éclairagisme.

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Book reviews

CONGENITAL ISOLATED VENTRICULAR SEPTAL DEFECT HAEMODYNAMICS CLINICAL FEATURES AND PROGNOSIS AFTER THE AGE OF TWO YEARS By Erik Sandoe 270 pages 22 figures and 5 tables Munksgaard Copenhagen 1963 Price 8 dollars

This extensive review of the hemodynamic findings in isolated ventricular septal defect the natural history of this anomaly and some of its manifestations at clinical and roentgen exa minations are based upon a series of 87 patients aged between 2 and 51 years The central thesis is concerned with the assessment of the interaction of pulmonary artery pressure pulmonary resistance and ratio of flow between the pulmonary and systemic circulations The presentation is comprehensive and clearly set forth and a number of tables and drawings make for easy reading of the text A study of the heamodynamics as revealed by repeated cardiac catheterizations at intervals of several years is of particular interest These with few exceptions proved to be stable over the years a finding that is at variance with reports in some other works For a roentgenologist interested in the background of this disorder the book supplies a rich source of information although less may be gained from the analysis of the roentgen findings The comparisons of heart volume determinations with the hemodynamic factors are valuable and enlightening The descriptions of cardiac configuration and the consideration of the differential diagnosis on the other hand do not appear to be entirely satisfactory The reviewer feels that this may be due to a failure to appreciate the size of the left atrium and the infrequent use of angiocardiography for the analysis of anatomical data This is somewhat beyond the aim of the author however and should not detract from the general merits of a monograph that mainly concerns a study of the functional derangements of isolated ventric ular septal defect For a reader interested in the historical aspects the introductory chapters offer a superb review of the evolution of the present day concept of ventricular septal defect from the days of Galen There is a useful summing up of the overall results and an extensive list of references adds to the value of the book

Ulf Rudhe

AN ATLAS OF VASCULAR RINGS AND RELATED MALFORMATION OF THE AORTIC ARCH SYSTEM By J R Stewart O W Kincaid and J E Edwards 171 pages and 216 illustrations Charles C Thomas Springfield Illinois 1963 Price 10 75 dollars

The authors present a systematic survey from the standpoint of embryology of the dif ferent congenital variations that have been observed in the aortic arch system and supplement their own material with that of about a dozen other investigators Descriptions and illustra tions of autopsy material from the main part of the work and illustrative roentgenograms are also included The book contains an extensive bibliography and can be recommended to workers in this field

Bjorn Nordenstrom

Lumbar Discography By J S Collis Jr 173 pages 66 figures and 118 tables Charles C Thomas Springfield Illinois 1963 Price 12 dollars and 75 cents

The author has employed an electronic computer to analyze the data from 2 175 lumbar discograms, in 572 of which the subject had been surgically explored and has assembled an impressive array of tables in a special chapter No clear definition as to what is meant by clinical diagnosis and surgical findings is given and the reader can consequently form no satisfactory idea of the reliability of the facts presented The tabulated information does not however appear to add any essentially new knowledge to what has already been published in this field

It is claimed that a herniated disc may be distinguished from a degenerated disc (without herniation) by means of discography if pain reactions are obtained on the intradiscal injection of contrast medium The reverse has however been convincingly reported in earlier publications a troublesome fact that the author explains by advancing the view that the discogram and pain recording will be misleading unless the films are obtained with the needle still in position Earlier studies based on clinical cases and necropsy material (Fernström 1960) have shown however that leakage of contrast medium through the needle track is of no practical significance either to the discogram or to the pain response

The author maintains that the early stage of partial rupture is in many cases an artefact although this is not supported by previous investigations on necropsy material (Erlacher and others) His views regarding the normal discogram are at complete variance with the criteria set up by Sieber many so-called normal discograms that in reality indicate an early stage with partial rupture are included in the chapter with an Atlas of Discograms The inclomplete analysis of the normal disc has also had an effect on the tabular review which shows a much greater number of pain reactions in normal discograms than has previously been reported As the reproductions of the discograms often leave much to be desired the reader is unable to decide whether the accompanying explanatory drawings truly represent the orginal illustration

A chapter devoted entirely to degenerative disc disease contains the statement that a degenerated disc (without herniation) is associated with back and leg pain The inclusion in this part of the book of a review on discogenic pain might not have been out of place but the literature on this subject like that on disc ruptures and abdominal pain seems to have been entirely missed by the author The surgical treatment of degenerative disc conditions based on pre operative discography is also discussed but again no mention is made of earlier findings

Despite these deficiencies the book has many merits The author stresses the importance of pain registration and the deleterious effect of local anaesthesia on such recordings The injection of methylene blue into a lumbar interspace showing a positive discographic finding to serve as a guide for surgical exploration appear to be an excellent idea The chapter entitled Discography Versus Myelography demonstrates beyond all doubt the superiority of the former for the detection of all forms of degenerated disc with or without root compression It would appear to the reviewer however that it is often difficult to distinguish between a herniated disc and a degenerated disc by means of discography and the fact that the author is of a different opinion must be attributed to his choice of cases The reviewer agrees in full with the author s statement that treatment of degenerated disc is not yet established however discography will be a means of future intelligent evaluation and investigation

The book is a valuable contribution to the literature on low back pain and sciatica and like the earlier publications gives support to the view that these pain states are not always synonymous with root compression The book should be of interest to neuroradiologists and neurosurgeons as well as to orthopedic surgeons

Ulf Fernström

ZAHNARZTLICHE RONTGENOLOGIE Von E Paerschke und R Dietze 154 Seiten Gustav Fischer Verlag Jena 1963 Preis 19 80 DM

This monograph gives a short account of the roentgenographic technique from the odontologic standpoint Roentgendiagnosis and pathology are not included

The first section deals with certain general aspects of roentgenology and concludes with a chapter on radiation protection the second section being devoted entirely to the technique of dental roentgen examinations Positioning and other measures of significance in intra-oral full mouth surveys are naturally treated in the greatest detail but the techniques for examining other parts of the skull are also considered Modern panoramic equipment such as the Panoramix and Paatero s pantograph are briefly described

A textbook with these limitations cannot of course aim to give more than a general review of the subject and it must be a matter of opinion as to what is to be included or excluded It would appear to the reviewer that it might have been an advantage to stress the value of supplementing the full mouth survey with bitewing views of the molar and premolar areas such films facilitate the diagnosis of marginal parodontopathy proximal caries and over hanging fillings Some mention ought also to have been made of Herulf's device since this is an excellent aid to positioning for extra oral views

The book is easy to read and contains many good drawings photographs and roentgenograms It is intended mainly as a textbook for the training of radiographers but should also prove useful to dental students as well as a reference book for dental practitioners Radiologists in other fields are likely to find the description of the positioning technique for full mouth surveys of considerable value

Arne Forsberg

THE SALIVARY GLANDS IN RADIOLOGICAL DIAGNOSIS By G F Garusi Bibl Radiol Fasc 4 160 pages 153 figures S Karger Basel 1964 Price 30 DM

No monograph on the diagnostic radiology of the salivary glands has been published since 1942 so that this work is well timed

The opening chapters are concerned with the anatomy and physiology of the glands and the author s standardised technique These are followed by analyses of the roentgen findings in normal and diseased glands Most space is given to the commonest abnormalities viz inflammatory lesions of the salivary glands and stone and tumours of the parotid and submandibular glands A short chapter is devoted to the sublingual salivary glands which can be examined roentgenographically only when they empty into Wharton s duct

The author advocates the use of water soluble contrast media and a modified Gullmo-Book Hederstrom cannula with an olive shaped stopper or a fine polythene catheter and manual injection As to the manual injection one wonders whether it might not be better to utilize the hydrostatic pressure in a vertical plastic tube as recommended by other authors instead of the less well controllable manual injection it must however be admitted that none of the author s 153 photographic reproductions shows any signs of extravasation Most of the illustrations are excellent The book is clear and concise contains 243 references and can be recommended to all roentgen departments interested in sialography

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Johan Folin

CLINICAL UROGRAPHY By John L Emmett 2nd edit Vol I—II 1294 pages 2016 figures W B Saunders London 1964 Price 17£ 10Sh

The book is edited by a prominent urologist and written with the assistance of a large number of urologists and radiologists The editor and almost all of the contributors are working at the Mayo Clinic where practically all work in clinical urography is done by the urologists An important advance has been made since the time of the previous edition in 1951 in that all new special examinations such as angiography are now performed by radiologists

The first chapters give a good and detailed account of the elements of clinical urography The presentation is usually good but contains some imperfections The authors for example use pyelography to distinguish a radiopaque gallstone from a stone in the kidney a distinction which can readily be made by using an oblique projection and pyelography is often used unnecessarily in the investigation of the upper urinary tract

The description of the diseases of the lower urinary tract and their radiological and clinical features is excellent Angiography especially lumbar aortography has received considerable space while selective angiography which is a far more important method is given only a few lines Urokon is described as the contrast medium of choice (together with Hypaque and Renografin) Urokon should not be used because of its high toxicity however For differentiation between cyst and tumor the authors recommend nephrotomography after intravenous injection of large amounts of contrast medium It should have been stressed that the method *is not so reliable as angiography The inclusion of lymphangiography* and some other methods in a section on miscellaneous procedures appears appropriate but placentography seems out of place

The book concludes with a concise and valuable survey of the use of radioactive isotopes in the clinic for diagnostic purposes

The illustrative material is abundant though of somewhat varying quality and often shows almost identical changes The book gives valuable information on the urologist s conception of the pathologic clinical and diagnostic aspects of the diseases of the urinary tract and it clearly shows the necessity of having radiologists perform the diagnostic radiologic examinations in urologic clinics

Frik Boysen

ACTA RADIOLOGICA

OFFICIAL ORGAN OF THE RADIOLOGICAL SOCIETIES OF
DENMARK FINLAND NORWAY AND SWEDEN

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RADIOLOGIC DEMONSTRATION OF THE LYMPHATIC CIRCULATION OF THE HEART

by

A CELIS H DEL CASTILLO H MARQUEZ, R ALCANTARA and D MIJANGOS

The relationship between the lymphatic system of the heart and the physiology and pathology of the organ is a subject that has been neglected although NUCK in the 17th century first described the lymphatic vessels of the heart together with the lymphatics of the uterus ovary and kidney SAPPEY (1874) documented the anatomy of the cardiac lymphatics verified later by PATEK (1939) and MILLER (1963) DRINKER (1939) identified the cardiac lymph node while the lymphatics of the mitral valve were described by EBERTH & BELAJEFF (1866) and MILLER et coll (1961) The composition and pressure of the cardiac lymph its protein and electrolyte and content and variation under functional conditions as well as its relationship with the blood proteins were all investigated by DRINKER et coll (1943) and during hypoxia and hypercapnia by MAURER (1940)

Several papers on endocardiac fibrosis and fibroelastosis have described these as being of obscure etiology and several hypotheses as to their pathogenesis have been advanced e g by THOMAS et coll (1954) ROSHAN (1955)

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Submitted for publication 10 November 1964

and SELYE (1958) In the past few years, the different endocardiac changes following experimental lymphatic obstruction have been described e g by SYMBAS (1963) MILLER (1961, 1963) reported morbid pathologic changes very similar to endocardiac fibrosis and fibroelastosis produced by chronic cardiac lymphatic stasis Histologic studies of endocardiac lymphatics have been published by SAMSEVA (1961) It appears that the cardiac lymph is a good index of the interchange between the interstitial space and the capillary circulation and that, together with the arterial and venous flow, it reflects the metabolism of the myocardiac fibres It seems there is a possibility of changes occurring in rheumatic valvulitis, cardiac insufficiency and infarction, and in acute and chronic myocarditis (MILLER 1963)

The immediate purpose of this investigation has been to add to the classic method of staining the heart lymphatic system for its radiologic demonstration so as to study any changes under different physiologic, pathologic and experimental conditions The literature to date has been reviewed, and although papers dealing with the experimental ligature of the efferent lymphatics as well as with the study of cardiac lymph under different conditions have been found there appears to be no communications on the roentgenologic demonstration of the system

Material and Methods Forty living dogs, 18 human cadaver hearts and 2 living bovine hearts were used The following methods were tried

I Direct lymphography, i e injection of the previously stained lymphatics by the technique of KINMOTH & TAYLOR The lymphatic collectors at the base of the heart were cannulated by DRINKER's technique, but it was not possible for either the catheter or the contrast medium to be passed towards the periphery due to the presence of valves at this level, only the main trunk and short spans of its branches were filled We also failed with the same technique when an attempt was made to make the injection from the apex towards the large collectors

II A suspension of China ink was deposited within the pericardium or myocardium by injection Histologic sections were then prepared

III Intramyocardiac injection of dyes by means of vertical sternotomy was made in dogs with or without ligating the efferent lymph vessel to stop the flow of the stained lymph Photographs were obtained through the thoracotomy wound and then of the heart after its removal, photographic enlargements were made of the tiny lymphatic vessels

IV Using the above mentioned technique a dyed opaque material, as prepared by one of us (R A), is injected and radiograms of the live animal are taken, the heart is then removed and further films obtained In order to test



Fig 1 Vital sta ni g of the heart w th sutures in the upper port on of the tv o subep cardial collect ng lymphatic vessels



F g 2 Close up of the same case Vital sta ning of the lymphatic circulation of the anterior aspect of the dog s heart



Fig 3 Circulation of a human heart stained post mortem Magnification view of the subepicardiac lymphatics anterior aspect of the apex



Fig 4 Vital staining of the lymphatics of the anterior aspect of the dog's heart roentgen film post mortem



Fig 5 Demonstration of the subepicardial lymphatics of the right and left ventricles filled with contrast material

the tolerance to the procedure the animal is placed on the roentgen table and left lateral thoracotomy is performed through an intercostal space The pericardium is opened and 1 ml of the opaque or non opaque staining medium is injected into the myocardium at the apex Films are then taken serially every 5 minutes up to one hour The thoracotomy is closed and the dog is watched during the postoperative period EKG is performed during the procedure

V A similar procedure is followed in the heart of human cadavers as well as of sacrificed bovines after removal Photographs and radiograms are then obtained

Results

China ink is observed to drain through the lymphatics and not through the blood capillary vessels in the histologic sections obtained by technique I With technique II it is possible to identify the subepicardiac plexus by means of colour photographs and close ups The plexus is either dilated or normal in appearance depending on whether or not the lymphatic flow has been

obstructed (Figs 1, 2 and 3) Conventional roentgenograms, as well as enlargements, of the subepicardiac plexus and cardiac nodes were obtained by technique III Superimposed images of the subepicardiac plexus and the corresponding lymph node were obtained with both procedures There are more or less important variations, but in general terms, and in agreement with SAPPEY and PATEK, the cardiac lymphatics follow the topography and distribution of the coronary vessels (Figs 4, 5 and 6)

The myocardium, the subepicardiac collector, and the supracardiac collector and node, as well as the efferent vessels in the neck, are evident in the 5 min film (Figs 7, 8 and 9) The contrast material in the myocardium persists but gradually decreases up to the last film The subepicardiac plexus appears rather early and increases in clarity of outline, reaching a peak at 20 min, to diminish and disappear at the end of 60 min The supracardiac collector and the node appear at 10 min and persist up to 60 min

Technique IV, in human and bovine hearts, permitted the draining of dyes or stained opaque media and the graphic representation in photographs and roentgen films of the subepicardiac lymphatic system A similar technique with mercury was used by SAPPEY The present authors have also used intramyocardiac injections of mercury in human cadaver hearts for roentgenography This procedure has however proved a failure, as only a few lymphatic vessels can be demonstrated and most of the mercury drains away through the blood system Beautiful radiograms of the peripheral coronary system may nevertheless be obtained

Roentgen enlargements of the site of the intramyocardial injection of the contrast substance showed ill defined accumulations of the medium which little by little started to resolve while outlining the muscle bundles, the interstitial spaces and finally the network of myocardiac lymphatic vessels from which the subepicardiac plexus originates

Discussion

Indirect lymphography has been achieved because the myocardiac lymphatic plexus, made up of rather thick capillaries, the thinnest of which is three times as large as the blood capillary vessels of the same area, is capable of absorbing the staining medium, which reaches a concentration high enough to be evident in the roentgen film It was felt in the first few cases that it was necessary to obstruct the lymphatic flow by either temporary or permanent ligatures in order to obtain a good filling of the blood vessels It was finally realized, however, that the medium is retarded at the lymph nodes and thus allows a good demonstration of the lymphatic system



Fig 6 Demonstration of the collecting lymphatic vessels of the right and left ventricles in a preserved bovine heart

The demonstration of the progress of the opaque and stained media *in the* lymphatic vessels in the cadaver was considered of considerable importance It is not the blood but the lymph vessels that become opaque and/or coloured This is due to morphologic factors and to their non uniform caliber with narrowings and dilatations the embossed outline caused by valves and also because of its flow into an ascending collector which drains into the cardiac node (see Fig 10) Simultaneous differential contrast filling of the coronary arteries and veins was performed for confirmation, and both systems were distinguished

The rate of flow of the medium was best appreciated in the lymphographic series it was found to be rather low since *it took* ten minutes for the medium to reach the cardiac node The persistence of the medium may be explained on the basis of a continuous drainage from the site of intramyocardiac injection PATEK ascribes the flow to the contraction of the cardiac muscle The present investigation indicates that in the cadaver the medium passes through the lymphatic capillary membrane due to its great permeability and the hydro static pressure and then vis a tergo follows the lymphatic pathways These facts raise the possibility of identifying the lymphatic system in autopsy



Fig. 7. Radiography during thoracotomy: there is contrast material in the apex, the right and left collecting vessels, and in the cardiac lymph node.



Fig. 8. Radiography during thoracotomy 5 min after injection of contrast medium into the myocardium. The ascending lymph vessels are seen.

material, just as SALLEY achieved the same result with mercury, and also the possibility of studying the absorption by the myocardium of drugs and other substances and their subsequent drainage into the lymphatic system.

The administration of the contrast material or stained media has no other electrocardiographic manifestation than the one due to the mechanic stimulus caused by the insertion of the needle, viz. frequent extrasystoles and occasionally short episodes of ventricular paroxysmal tachycardia which subside when the needle is withdrawn and the organ falls back into place. The graphs obtained after closure of the thoracic wall are in every way similar to those obtained pre-operatively, although a lowering of the voltage in the EKG components is occasionally seen. As was to be expected, animals have quite well tolerated the myocardiac puncture and the injection of contrast medium. The procedure has so far not been performed in any living human subject.

There is unquestionably a gap in the study of cardiac physiology and pathology in relation to the lymphatic system. The pathologist never reports on



Fig 9 Same case as in fig 8 but 10 min after injection of the medium Supracardiac lymph node and efferent lymph vessels are demonstrated



Fig 10 Same case as in figs 8–9 but 40 min after injection The e is still contrast medium in the myocardium the lymph node and vessel up to the neck the medium has disappeared from the subepicardial collector

changes or does so only in the exceptional cases of neoplastic disease with lymphatic permeation in which the changes are only too apparent Most certainly this is due to the fact that their identification with present day techniques is difficult both under normal and pathologic conditions

There appear to be two elements of interest and worthwhile a study by cardiac lymphography One is the myocardiac plexus as demonstrated by injection and the other the subepicardiac system A detailed study of the former through microlymphography might furnish interesting data regarding changes in cases of myocardial infarction, myocarditis and cardiac insufficiency

Once the present authors succeed in developing a method by which a good morphologic representation of the system can be achieved they intend to

apply it to the study of human cardiac pathology, or to experimentally induced changes in the animal. Such studies may or may not disclose abnormalities in the system but they will undoubtedly prove of value.

It would seem that the indirect method, as it has been used in the heart, may be applied *to visceral lymphangiography*. *The opaque medium*, when instilled into the parenchyma of certain organs, might be absorbed by the lymphatic capillaries and drain towards the collectors and the corresponding lymph nodes, and produce a picture of the whole system. The peripheric plexuses might be demonstrated by the microlymphangiographic technique.

SUMMARY

The possibility of demonstrating the cardiac lymphatic system roentgenologically as a method additional to the classic one of staining is discussed. The material consisted of 40 living dogs, 18 human cadaver hearts and 2 living bovine hearts. Five methods were tried. The results obtained appear to be promising.

ZUSAMMENFASSUNG

Eine neue Methode zur Röntgendarstellung des Lymphsystems des Herzens als Ergänzung der alten Anfärbemethode wird beschrieben. Als Material wurden die Herzen von 40 lebenden Hunden benutzt sowohl wie 18 tote Herzen und 2 lebende Ochsenherzen. Fünf Methoden wurden probiert. Die Resultate erscheinen versprechend.

RÉSUMÉ

Les auteurs ont étudié les possibilités de mettre en évidence radiologiquement le système lymphatique du coeur comme méthode complémentaire de la méthode classique de coloration. Leur matériel comprenait 40 chiens vivants, *18 coeurs de cadavres humains et deux coeurs* de bovins vivants. Ils ont essayé cinq méthodes. Les résultats obtenus paraissent encourageants.

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HERNIA OF THE LUNG

Brief survey and report of two cases

by

P. BIDSTRUP, J. MUNCK NORDENTOFT and B. PETERSEN

Hernia of the lung may be defined as a protrusion of pulmonary tissue, covered by parietal and visceral pleurae, through an abnormal aperture in the walls of the normal thoracic cavity.

According to MOREL-LAVALLÉE, hernia of the lung may be classified according to localization in (1) cervical, (2) thoracic, and (3) diaphragmatic, and according to aetiology in (1) congenital and (2) acquired, the latter being subdivided into (a) traumatic, (b) consecutive, (c) spontaneous, and (d) pathological.

Only one well documented case of diaphragmatic hernia of the lung, reported by BLATT in 1882, is on record. In the presence of a normal positive pressure difference between the abdominal and thoracic cavities, pulmonary tissue cannot herniate through a weak area of the diaphragm. If, however, considerable insufficiency of the abdominal musculature is present, the intra-thoracic pressure may, e.g. during coughing, exceed the intra-abdominal pressure and result in diaphragmatic pulmonary herniation.

Congenital herniae are due to a developmental defect in the thoracic wall, most frequently in the supraclavicular fossa or anteriorly at the junction of a rib and its costal cartilage.

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Traumatic herniae occur in association with fracture of ribs, penetrating lesions and surgical interventions There is no clear line of distinction between these herniae and the consecutive herniae that develop some time after localized trauma

Spontaneous herniae occur in the presence of a local impairment of the thoracic wall in association with increased intrathoracic pressure produced by e g protracted coughing or lifting of heavy weights The impairment may be due to muscular atrophy or the absence of ribs These herniae generally occur in the cervical region possibly because of a congenital weakness in Sibson s fascia but are nevertheless termed spontaneous

A pathologic hernia develops when the thoracic wall has been weakened by a pathologic process e g a lung abscess penetrating the wall an abscess of the wall or caries of a rib

Frequency MONTGOMERY & LUTZ (1925) analysed the 165 cases that had then been reported as regards localization and aetiology where this was possible HISCOE & DIGMAN (1955) published a similar analysis of the cases from 1925 to June 1954 by which time the total number had increased to 233 The literature now includes 23 additional cases published within the period from June 1954 to July 1963 The two cases now reported brings the total number on record to 258

Classification according to localization

	MONTGOMERY & LUTZ	HISCOE & DIGMAN	BIDSTRUP NORDENTOFT & PETERSEN	Total No	%
Cervical	16	17	22	55	35
Thoracic	62	39	3	104	65
Total	78	56	25	159	100

Classification according to aetiology

	MONTGOMERY & LUTZ	HISCOE & DIGMAN	Total No	%
Congenital	29	11	40	18
Acquired				
Traumatic or consecutive	83	32	115	52
Spontaneous	53	11	64	29
Pathologic	0	2	2	1
Total	165	56	221	100

Symptoms. These are usually few and vague. Strangulation of the hernia with signs of local inflammation, may occur in rare cases.

Diagnosis. The diagnosis may be made in the presence of a soft, crepitant protrusion, which is reduced in size on quiet respiration and again bulges forward on coughing, forced expiration, or Valsalva's manoeuvre. The defect in the chest wall can often be palpated. The diagnosis may be confirmed radiologically by the demonstration of protrusion of pulmonary tissue on tangential exposures. Conditions that require differentiation are tumours of the chest wall (lipoma, angioma), subcutaneous emphysema, pleural empyema and cold abscess.

Treatment. The hernia will rarely disappear spontaneously but therapeutic measures are often unnecessary. When treatment is required, this may be either palliative, with some form of truss that keeps the hernia in place, or surgical, with closure of the defect in the chest wall. According to MAURER & BLADES, repair of the defect is best performed by means of periosteal flaps from the adjacent ribs.

Case reports

Case 1. Labourer, aged 38, who sustained severe trauma to the right side of the anterior chest wall in June 1951. After sudden application of the brakes, he was caught between the driver's cab of a lorry and a heavy load which was displaced forwards. Just after the accident he expectorated a small amount of bloody sputum. He was referred for rib fracture but both clinical and radiologic examinations were negative. A further roentgen examination in August 1951 produced the same result.

The patient complained of moderate pain in the right half of the chest, especially during work and on coughing. The pain increased in intensity two and a half months after the accident and as the patient became febrile and dyspnoeic, he was admitted to hospital in October 1951. Physical examination on admission revealed a depression of the right anterior chest wall just below the clavicle, i.e. at the site of the trauma. Chest radiography revealed infiltration in the upper part of the right lower lobe. There was no fluid in the pleural cavity. Repeat roentgenography on 2 November disclosed that the infiltration was unchanged, and a small amount of fluid was now present in the right pleural cavity.

A diagnosis of pleuropneumonia was made, and the patient was treated with penicillin after which the body temperature returned to normal. Control radiography during the hospital stay showed distinct regression of the infiltration. The patient was discharged on 18 November 1951, and was fully able to work 6 months after the injury.

Four months after the accident the patient noticed that straining efforts caused a bulging at the site of the trauma. Two weeks later an area of pressure at the site was apparent (Fig. 1, upper views). On coughing or on Valsalva's manoeuvre, a bulge the size of a goose

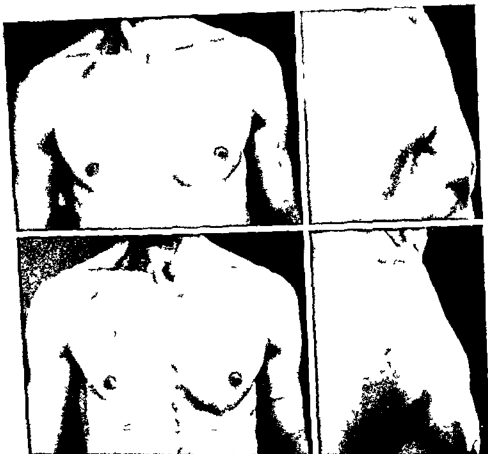


Fig 1 Ca e 1 *Upper* Normal resp ration Slight impress on on the right anterior chest wall *Lower* During Val alva s manoeuvre Bu'g ng of right anterior chest wall

egg appeared in the second right intercostal space in the midclavicular line (Fig 1 lower views) The chest wall appeared to yield in this region but an actual hernial orifice could not be felt Chest radiography indicated normal conditions, but special exposures of the right side of the anterior chest wall during Valsalva s manoeuvre revealed two rounded zones of lessened density protruding between the ribs into the soft parts (Fig 2) Similar exposures during inspiration disclosed normal conditions The radiologic diagnosis was one of pulmonary hern a in the second right intercostal space The patient refused thoracoplasty as the lesion caused only slight d scomfort

At control examinations in 1956 and 1963 (5 and 12 years after the accident) the same rad o-logic changes during Valsalva s manoeuvre were observed The condition was also unchanged clin cally Coughing produced a swelling of unchanged size which persisted during Valsalva s manoeuvre the swelling was soft and crepitant The hernia could not be produced when the



a b

Fig. 2. Case 1. a) A.p. view. Right anterior chest wall during Valsalva's manoeuvre. Rounded zone of lessened density in the second intercostal space. b) Tangential view during Valsalva's manoeuvre. Protrusion of pulmonary tissue into the soft parts.

patient contracted the pectoralis major muscle, it was assumed that the hernia was due to atrophy of the intercostal musculature.

Case 2. Boy, aged 11, who was kicked by a cow in July 1951 in the region of the right nipple, developed a small excoriation with extravasation of blood into the soft tissues at the site. The boy was referred to hospital four days later when it was noticed that on coughing a small bulge appeared between the ribs at the site of the trauma. Physical examination disclosed a hernia the size of a hen's egg anteriorly in the fifth right intercostal space. Chest radiography disclosed no rib fractures. A tangential view obtained during forced expiration revealed a typical hernia of the lung (Fig. 3).

The patient was treated with a special truss and was subjected to several clinical and radiologic control examinations. At the last examination in August 1953, i.e. 2 years after the trauma, the hernia was smaller than on previous occasions, presumably because the musculature had become stronger in the meantime. Further treatment was therefore considered unnecessary.

The patient, who is now 24 years old and a medical student, informed us by letter in January 1964 that he still has a "hole in his chest", where a small bulge appears on expiration and a slight depression on inspiration; the bulging becomes maximal on coughing or sneezing. The lesion causes no discomfort.



Fig 3 Case 2 Tangential view of right anterior chest wall Protrusion of pulmonary tissue into the soft parts of fifth intercostal space

Discussion

It appears that Case 1 must be classified as a consecutive thoracic hernia of the lung and that Case 2 is a traumatic thoracic hernia

Our studies of the literature since 1954 were especially directed to the localization of the herniae and a distinct divergence between the ratio of cervical to thoracic herniae reported by previous investigators (33 101) and our own observations (22 3) was apparent It would appear that cervical herniae have the highest frequency and it is possible that the same opinion on the part of other observers may have led to the publication of fewer cases of this variety FENICHEL & EPSTEIN who reported 19 cases of cervical herniae stated in our experience supraclavicular herniation of the lung is not unusual

Acknowledgements

The first case history was presented at a meeting of the Danish Radiological Society in May 1951 During the subsequent discussion Professor Gregers Thomsen mentioned a similar case and we are greatly indebted to him and to Professor F Therkelsen who kindly placed the case records and the roentgenograms at our disposal for this publication

SUMMARY

Two cases of hernia of the lung are described bringing the total number of cases reported up to 1963 to 258 Both cases were subjected to follow up examinations for 12 years after the trauma The herniae were treated conservatively and caused no serious discomfort

ZUSAMMENFASSUNG

Zwei Falle von Lungenhernie werden beschrieben diese bringen die Gesamtzahl der bis 1963 veroffentlichten Falle auf 258 Beide Falle wurden bis auf zwolf Jahre nach der ursprunglichen Verletzung regelmassig nachuntersucht Die Behandlung war in beiden Fallen konservativ und die Patienten hatten keine nennenswerten Beschwerden

RÉSUMÉ

Présentation de deux cas de hernie du poumon portant le total des cas décrits jusqu à 1963 à 258 Ces deux cas ont été surveillés pedant 12 ans apres le traumatisme Le traitement a été conservateur et ces hernies n ont pas causé de gene sérieuse

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ROENTGENOLOGIC DIAGNOSIS OF ATYPICAL COARCTATION OF THE AORTA

by

T KOZUKA T NOSAKI, K SATO and K IHARA

Atypical coarctation of the aorta with an elongated occlusive lesion in the sub isthmic parts of the thoracic and abdominal aorta appears to be a rare condition the main tributaries of the aorta, especially the brachiocephalic arteries may be affected This was recognized as a pathologic entity by TAKAYASU who published the first description

The attention of clinicians has been drawn to absent or diminished pulses in the arms and neck and the term pulseless disease has been applied by many authors As histologic studies have revealed a non specific inflammatory process of the affected arteries various other terms for the condition have also been applied e g branchial arteritis (EDLING et coll) obliterative brachiocephalic arteritis (GIBBONS & KING) The occlusive changes however may occur not only in the brachiocephalic arteries but in the thoracic and abdominal aorta as well so that terms such as atypical coarctation of the aorta , elongated coarctation of the aorta (MILLOY & FELL) and middle aortic syndrome (SEN et coll) have been proposed Atypical coarctation of the aorta and pulseless disease are thus regarded as the same entity (INADA et coll , inter alios)

Material and Methods Conventional chest roentgenography and aortography were performed in 26 cases during the last 5 years and formed the basis of the present analysis These cases consisted of 23 females and 3 males whose ages

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ranged from 10 to 39 years but who were mostly in the third decade, all were Japanese Sex and age distribution were as follows

	Under 20 years	Between 20—29 yrs	Between 30—39 yrs	Total number
Males	0	3	0	3
Females	6	12	5	23

The pulses in one or both upper limbs were weak or absent in all the cases, and in some cases they were weak in the lower limbs as well

Percutaneous retrograde aortography was the method of choice to detect the site and degree of involvement, and thoracic and abdominal aortograms were obtained by two injections of contrast medium Intravenous aortography was employed only in those cases in which retrograde aortography had been unsuccessful or seemed to be dangerous No serious complications occurred

Radiologic findings

Conventional roentgenologic findings Characteristic reports on conventional roentgenograms of the chest are recorded below

Prominent aortic knuckle	21 cases
Descending aorta with irregular contour	19 »
Protrusion of pulmonary segment	16 »
Increased convexity of left lower cardiac segment	12 »
Pulmonary vessels of abnormal appearance	10 »

Typical roentgenograms are shown in Figs 1, 2 and 3

One of the more interesting roentgenologic features, recognized in 21 cases, was the prominence of the aortic knuckle The contour of the left border of the descending thoracic aorta was found to be rigid, jagged and wavy in 19 cases

Definite enlargement of the pulmonary conus was thought to be present in 16 cases, and dilatation of the left ventricle of the heart was noted in 12 of the cases Narrowing of the pulmonary vessels, usually of the upper part, was evident in 10 cases (Fig 4)

A small protrusion with calcareous deposits at the proximal part of the descending thoracic aorta in one case (Fig 6), and a massive lesion at the level of the diaphragm in another case, proved to represent an aneurysm of which there was no indication in the ordinary roentgenograms (Fig 5)

No notching of the ribs was demonstrable in this series

Table 1

Appearances of aorta at aortography in 26 cases of atypical coarctation of the aorta

	Ascending	Arch	Descending	Abdominal
Dilatation	15	11	3	2
Narrowing	1	1	21	12
Irregularity of contour	4	12	26	17
Aneurysm formation	1	1	3	1
Normal	9	6	0	3
Not clarified	0	0	0	4

Angiographic findings Retrograde aortography was performed in 19 cases intravenous aortography in 10, and both examinations in 3 cases The changes noted in the aorta and its branches are summarized in Tables 1 and 2

The typical roentgenologic features in the aortograms of these cases were dilatation of the ascending aorta and aortic arch and narrowing of the descending aorta

Fifteen cases presented evidence of dilatation of the ascending aorta and in 11 cases there was also some degree of dilatation of the aortic arch, while narrowing could be detected in only one case Irregularities of the contour of the ascending aorta and aortic arch were frequently present

In all the cases the descending aorta was narrowed either in its thoracic or abdominal parts and irregular in outline The narrowed lumen of the aorta extended over several centimeters or more, and the smallest area of involvement most frequently lay at the lower half of the thoracic part The aorta immediately above or just below the coarctation was frequently found to be dilated and the contour of the inner surface of the aortic wall appeared to be rigid and irregular and the involved part of the wall of the aorta markedly thickened

The occlusive lesion involving one or more arteries arose from the aortic arch in all 26 cases The angiograms provided evidence that these stenosed

Table 2

Involvement of systemic arteries revealed by angiography in 26 cases of atypical coarctation of the aorta

Brachiocephalic arteries	26
Intercostal arteries	12*
Coeliac axis	3
Renal arteries	12

Aortograms revealing the lesions in the intercostal arteries and coeliac axis were adequate in 19 cases

* The renal arteries were visible in 17 cases



Fig 1 Case 1 Large aortic knuckle with concave outline of descending aorta *Irregular and narrow vessels in both upper lung fields*

arteries were associated with pre and/or post stenotic dilatation In 12 cases, the examination failed to present evidence of normal filling of the intercostal arteries

As regards the main branches of the abdominal aorta, the renal arteries were predominantly affected These were slightly or moderately obstructed in 6 cases and markedly obstructed in a further 6 cases, the coeliac axis was however rarely involved

Angiocardiography offers an opportunity of determining any changes in the pulmonary artery In an extreme case, of a 20 year old female investigated *in this series, angiography failed to show filling of the right pulmonary artery* (Fig 4)

Case reports

Case 1 Female aged 24 complaining of fatigue and of numbness or coldness of the extremities for many years worse on exertion and relieved by rest On admission the pulses of the femoral arteries were impalpable bilaterally B P 138/82 in the right and 122/82 in left brachial artery

Conventional chest films revealed dilatation of the aorta and irregularity of outline and narrow, irregular vessels in the upper part of the lungs (Fig 1)



Fig 2 Case ? a) D latation of the ascending aorta and marked stenosis of the aortic arch and de scend ng aorta Collater l vess ls to the lowe half of the body b) Stenoses of abdom inal aort a and il ac a t r es and narrow ng of the left renal artery

At angiography multiple pulmonary artery stenoses with irregular contours in the upper parts of the lungs v ere evident The descending aorta and the right common carotid artery wer found to be stenosed and the left subclavian artery to be obstructed Intravenous aortography was performed following insertion of a Teflon graft The abdominal aorta was com pletely obstructed and collateral vessels v ere v ell developed

Case 2 Female aged ?2 admitted to another hospital unconscious with high blood pressure left hemiplegia and left facial paralysis On examination nine months later B P 190 70 in the right and 172/115 in left brachial artery pulsation of the femoral artery could hardly be felt Systolic murmurs were audible in the second intercostal space along the right sternal border Conventional roentgenography of the chest revealed that the descending aorta was irregular in outline while aortography disclosed marked narrowing of a large part of the aorta with considerable irregularity and development of many collaterals Associated stenoses of the left subclavian artery left renal artery and both iliac arteries were also present (Fig 2)

Case 3 Female aged 1? A year prior to admission to hospital absence of the right radial pul e and high blood pressure in the left arm had been noted by several examiners When ad mitted the patient was complaining of vertigo palpitation numbness and coldness of the right upper extrem ty and general malaise The pulses of the right radial artery and the right carotid artery were absent systolic murmurs were audible on the left side of the neck corre sponding to the carotid artery The blood pressure was 180/120 in the left brachial artery but it could not be measured in the right brachial artery it was 144/90 in the left lower leg and faint in the ri ht



Fig. 1. Case 1. Large aortic knuckle with concave outline of descending aorta. Irregular and narrow vessels in both upper lung field.

arteries were associated with pre- and/or post stenotic dilatation. In 12 cases, the examination failed to present evidence of normal filling of the intercostal arteries.

As regards the main branches of the abdominal aorta, the renal arteries were predominantly affected. These were slightly or moderately obstructed in 6 cases and markedly obstructed in a further 6 cases, the coeliac axis was however rarely involved.

Angiocardiography offers an opportunity of determining any changes in the pulmonary artery. In an extreme case, of a 20 year old female investigated in this series, angiography failed to show filling of the right pulmonary artery (Fig. 4).

Case reports

Case 1. Female, aged 24, complaining of fatigue and of numbness or coldness of the extremities for many years, worse on exertion and relieved by rest. On admission the pulses of the femoral arteries were impalpable bilaterally. B.P. 138/82 in the right and 122/8? in left brachial artery.

Conventional chest films revealed dilatation of the aorta and irregularity of outline and narrow irregular vessels in the upper part of the lungs (Fig. 1).



Fig 2 Case 2 a) Dilatation of the ascending aorta and marked stenosis of the aortic arch and descending aorta Collateral vessels to the lower half of the body b) Stenoses of abdominal aorta and iliac arteries and narrowing of the left renal artery

At angiography multiple pulmonary artery stenoses with irregular contours in the upper parts of the lungs were evident The descending aorta and the right common carotid artery were found to be stenosed and the left subclavian artery to be obstructed Intravenous aortography was performed following insertion of a Teflon graft The abdominal aorta was completely obstructed and collateral vessels were well developed

Case 2 Female aged 22 admitted to another hospital unconscious with high blood pressure left hemiplegia and left facial paralysis On examination nine months later B P 190/70 in the right and 172/115 in left brachial artery pulsation of the femoral artery could hardly be felt Systolic murmurs were audible in the second intercostal space along the right sternal border

Conventional roentgenography of the chest revealed that the descending aorta was irregular in outline while aortography disclosed marked narrowing of a large part of the aorta with considerable irregularity and development of many collaterals Associated stenoses of the left subclavian artery left renal artery and both iliac arteries were also present (Fig 2)

Case 3 Female aged 19 A year prior to admission to hospital absence of the right radial pulse and high blood pressure in the left arm had been noted by several examiners When admitted the patient was complaining of vertigo palpitation numbness and coldness of the right upper extremity and general malaise The pulses of the right radial artery and the right carotid artery were absent systolic murmurs were audible on the left side of the neck corresponding to the carotid artery The blood pressure was 180/120 in the left brachial artery but it could not be measured in the right brachial artery it was 144/90 in the left lower leg and faint in the right

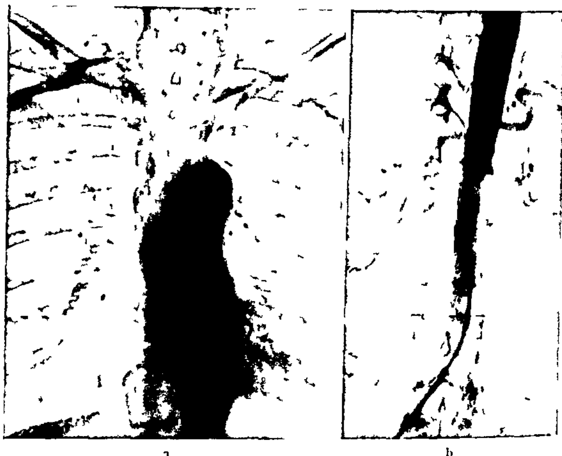


Fig 3 Case 3 Aortography Stenosis of the descending aorta with thickening of the wall stenosis of the right subclavian artery no filling of the intercostal arteries Stenosis of the common carotid arteries and the renal arteries especially on the left side

Conventional roentgenography of the chest revealed enlargement of both sides of the heart while thoracic aortography disclosed stenosis and marked irregularity in the descending aorta There was also evidence of stenosis of the common carotid arteries as well as of the right subclavian arteries (Fig 3a) stenosis of both renal arteries was present (Fig 3b)

Case 4 Female aged 20 who two years previously had been treated for pulmonary tuberculosis was admitted complaining of recurring attacks of syncope and blurring of vision which had become progressive

Conventional films of the chest revealed narrow pulmonary vessels on the right side deviation of the heart to the right and elevation of the right cupola of the diaphragm (Fig 4a)

At angiography the right pulmonary artery was not filled and slight stenosis of the descending aorta as well as occlusion of the left carotid artery and the subclavian arteries were present (Fig 4b)

Case 5 Female aged 19 admitted with a B P of 230/120 in the right brachial artery and systolic murmurs in the mid dorsal region



Fig 4 Case 4 a) Deviation of the heart to the right narrow vessels in the right lung and elevation of the right side of the diaphragm b) Angiography No filling of the right pulmonary artery

Percutaneous retrograde aortography revealed marked narrowing of the aorta with a thin walled aneurysm at the level of the diaphragm (Fig 5) The aneurysm was successfully removed

Case 6 Female aged 39 with a history of hypotension and vertigo of three years duration On admission the radial pulses were barely palpable and systolic murmurs were audible over the abdominal aorta and the right carotid artery B P right arm 84/70 left arm 98/90 The blood pressure could not be measured in the lower extremities

Conventional roentgenography revealed prominence of the aortic arch with a fixed out line of the descending aorta and diminution in the pulmonary vascular markings A small partially calcified protrusion proximal to the origin of the descending aorta suggested an aneurysm (Fig 6a)

Aortography disclosed bulging of the lateral wall of the descending aorta and coarctation at the level of the 10th dorsal vertebra there was also occlusion of the bilateral subclavian *arteries (Fig 6b)* Subsequent aortography demonstrated moderate narrowing of the abdominal aorta with bilateral stenoses of the renal arteries and involvement of the coeliac axis

Discussion

The pathologic changes and roentgenologic appearances of the aorta in pulseless disease have not often been described Stenosis dilatation and aneurysm formation of the aorta in association with stenosis of the brachiocephalic arteries were observed in the present series

Changes due to chronic inflammation are always evident histologically in all the layers of the arterial wall in this condition, of these, degeneration and



Fig. 5. Case 3. Retrograde aortography. Marked stenosis of the descending aorta and a large aneurysm at the level of the diaphragm. The brachiocephalic arteries and the coeliac axis are all involved.

destruction of the elastic media are the most important. The intima is secondarily proliferated and becomes thrombosed, occlusion occurring later (NASU); the media thus becomes weakened, which results in stenosis, dilatation and aneurysm formation.

Absent or weak pulses in the arm and neck indicate occlusion of the brachiocephalic arteries; such signs in the femoral arteries suggest atypical coarctation of the aorta. A review of the present cases elicits the interesting fact that the arterial pressure of the lower limbs was higher than normal in some of the cases; marked hypertension was also noted in non-affected arms. These findings indicate the presence of systemic hypertension.

Systemic hypertension in this disease has been supposed to be caused by circulatory disturbances around the carotid body and aortic arch, which are known to act as a pressoreceptor to regulate the blood pressure (LAMPEN). On the other hand, renal artery stenosis may be responsible for aggravating ischemia



Fig 6 Cas 6 a) Prominent aortic knuckle with small partly cal ified protrus on at the orig n of an irregular descend ng aorta slight dilatation of the left lower segment of the heart narrow irregular vessels in the upper part of the left lung b) No tog aphy Sl ght d latat on of the asc nd ng aorta and ao tic arch with a protrusion at the origin of the descending aorta and a stenotic area at the level of D10 Obstruction of both subclavian arteries filling of the collateral vessels in the reg on of the neck and shoulders inte costal and b onchial a teries not filled

of the renal parenchyma and thereby to cause an increase in blood pressure This mechanism of increase in blood pressure has been explained as one of the causes of hypertension in atypical coarctation of the aorta (ASK UPMARK & FAJERS) This opinion has been supported by experiments (INADA) It is generally accepted that the most frequent manifestations are occlusive changes in the renal arteries

The value of aortography by either the retrograde or the transvenous route has therefore become well established in the diagnosis of pulseless disease or atypical coarctation of the aorta These procedures are essential for the determination of the location and degree of the lesion as well as for planning any surgical intervention for the relief of symptoms

It is obvious that notching of the ribs cannot develop following obstruction of the intercostal arteries Contrast filling of the coronary arteries was infre quently obtained in the present material this sign is however of little account

because of the difficulty in demonstrating the coronary arteries by ordinary thoracic aortography.

No contrast filling of the right pulmonary artery was obtained by angiocardiography in the case illustrated in Fig. 4, so that aplasia of the pulmonary artery, associated with atypical coarctation of the aorta, had to be considered. However, this was thought unlikely, because complete obstruction of the right pulmonary artery may be present as one of the manifestations of atypical coarctation of the aorta with involvement of the systemic arteries. The same finding has been verified in autopsy cases (FROVIG & LOKEN, NASU).

It is as well to emphasize that conventional roentgenography of the chest may be sufficient to confirm the clinical findings. Roentgenologic signs, such as prominent aortic knuckle, irregular outline of the descending thoracic aorta, dilatation of the left ventricle of the heart and pulmonary conus, as well as narrow irregular pulmonary vessels, have been noted by EDLING et coll., and by IINUMA; it was confirmed at angiography in the present material. It is thus apparent that a definitive diagnosis of atypical coarctation of the aorta depends essentially on the conventional chest film and can be made in more than 60 per cent of cases. The correct diagnosis was established by ordinary roentgenography in 17 of the 26 cases of the material.

Acknowledgement

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SUMMARY

Twenty six cases of atypical coarctation of the aorta were studied roentgenologically. The characteristic appearances evident in conventional roentgenograms of the chest and in thoracic and abdominal aortograms are reviewed and discussed. It would seem that the condition tends to involve not only the aorta but arteries as well, such as the brachiocephalic, renal and pulmonary arteries.

ZUSAMMENFASSUNG

Sechsundzwanzig Fälle von atypischer coarctatio aortae wurden radiologisch untersucht. Die Veränderungen nach gewöhnlichen Röntgenaufnahmen und nach thorakaler oder abdomineller Aortographie werden besprochen und erörtert. Es wird angenommen, dass die Veränderung sich nicht auf die Aorta beschränkt, sondern auch die Nieren- und Lungenarterien beeinflusst.

RÉSUMÉ

Vingt six cas de coarctation aortique atypique ont été étudiés radiologiquement Les auteurs rappellent et étudient les images caractéristiques visibles sur les radiographies simples du thorax et sur les aortographies thoraciques et abdominales Il semble que cette affection tend à toucher non seulement l aorte mais aussi des arteres comme les arteres brachiocépha liques rénales et pulmonaires

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FIBROMUSCULAR HYPERPLASIA OF THE RENAL ARTERIES WITHOUT HYPERTENSION

by

LARS BJORK and STIG FAGERBERG

It is well known that stenosis of the renal arteries may cause arterial hypertension. Arteriosclerosis is the most common causal factor of stenosis although it may occasionally be encountered in association with fibromuscular hyperplasia. This condition gives rise to irregular hyperplasia of muscular and fibrous elements in the media of the distal two thirds of the arteries producing multiple strictures of characteristic angiographic appearances. Most of the patients, 80 to 90 % of whom are women, are between 20 and 50 years of age. Typical multiple strictures of the distal parts of the right renal artery are shown in Fig. 1, in a 36 year old woman with a blood pressure of 230/130 which became normal after nephrectomy. The histologic examination disclosed fibromuscular hyperplasia.

Fibromuscular hyperplasia seems to have been first described by LEADBETTER & BURKLAND (1938). However it is only in the last three or four years that the disease has received more widespread attention. This is probably explained by the increasing interest in arterial hypertension, and the more

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Fig 1 Typical multiple strictures of distal part of right renal artery

general use of renal angiography in this condition PALUBINSKAS & WYLIE in 1961 described 11 cases and more than 230 cases have since then been reported upon (WYLIE PERLOFF & WELLINGTON 1962 MEANEY & DUSTAN 1963 SUTTON & BRUNTON 1963 POUTASSE 1964 DE BAKEY MORRIS MORGAN et coll 1964 and others)

Fibromuscular hyperplasia is always associated with arterial hypertension, although PALUBINSKAS & RIPLEY (1964) mentioned that it was absent in one of their cases they also found angiographic changes characteristic of fibromuscular hyperplasia in abdominal vessels other than the renal arteries in eight other cases

The purpose of this investigation was to study the frequency of fibromuscular hyperplasia in a material of 338 routine renal angiographies performed during a 5 year period Hypertension was only one of the several indications for angiography

Renal artery stenosis was found in 33 cases in 20 of which it was judged to be arteriosclerotic Seven cases had appearances characteristic of fibromuscular hyperplasia 2 had periarterial fibrosis 2 were caused by pressure of metastases from malignant tumours and in 2 cases the etiologic origin of the stenosis remained unknown No evidence of fibromuscular hyperplasia was found in abdominal vessels other than the renal arteries

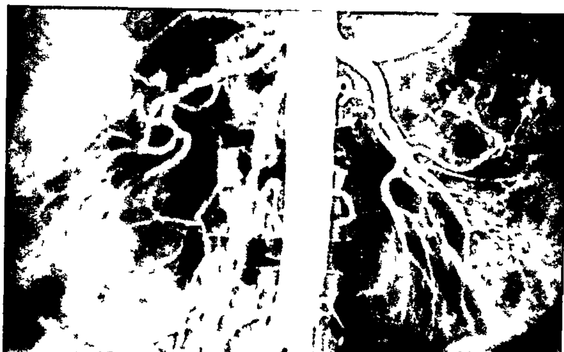


Fig 2 Large partly highly vascularized tumour arising from the left kidney multiple strictures typical of fibromuscular hyperplasia in right renal artery

The 7 cases of fibromuscular hyperplasia were all women between 20 and 50 years of age They all had strictures of the right renal artery, in one case there was also a stricture in the left renal artery Marked arterial hypertension with a systolic blood pressure of about 200, and a diastolic blood pressure above 120 mm Hg were present in 5 of the cases There was however no arterial hypertension in the other two cases These latter are described below

The first case was one of a 49 year-old woman who was admitted with acute left sided abdominal pain and a large palpable mass Renal angiography disclosed a large partly highly vascularized tumour on the left side, probably arising from the kidney Multiple strictures, with appearances typical of fibromuscular hyperplasia, were present in the right renal artery (Fig 2) At operation the tumour was found to be a lipofibrosarcoma Following radiation treatment the patient has recovered, and the blood pressure has remained normal

The second case was one of a 42 year old woman who had had a saddle embolus removed from the bifurcation of the aorta six months before first being seen in this hospital The embolus was found to be a myxoma, probably originating in the left side of the heart Angiocardiographies failed to demonstrate any tumour remaining in the heart The patient is symptom free



Fig 3 Structures typical of fibromuscular hyperplasia in right renal artery

two years after the episode and the blood pressure is normal Changes characteristic of fibromuscular hyperplasia were found in the right renal artery at a follow up abdominal aortography (Fig 3)

It is interesting that the angiographic changes described as typical of fibromuscular hyperplasia may occur in the renal arteries in cases without arterial hypertension Renal artery stenosis caused by fibromuscular hyperplasia seems to be no different in this respect from that of other origin The fact that the present material includes other diseases as well as arterial hypertension may be an explanation why two cases were found in this relatively small series

The origin of fibromuscular hyperplasia remains obscure Mechanical factors such as stretching of the renal arteries have been mentioned Its predominance in women has led to theories of hormonal influence on the disease The present two cases may support the opinion that congenital malformation of the mesenchymal structures of the body may be involved Both had peculiar tumours originating from mesenchyma beside the changes in the renal arteries

A case with other mesenchymal manifestations had been described by MacDonald & MacMillan (1963) who found cystic disease of the kidneys and a dissecting aneurysm of the aorta in a case of hypertension and fibromuscular hyperplasia of the renal arteries

SUMMARY

Seven cases of fibromuscular hyperplasia of the renal arteries were found in a material of 338 renal angiographies. Five of them had arterial hypertension with characteristic clinical and radiographic findings but there was no arterial hypertension in two cases with angiographic changes typical of fibromuscular hyperplasia.

ZUSAMMENFASSUNG

Sieben Fälle von fibromuskulärer Hyperplasie der Nierenarterien wurden an einem Material von 338 renalen Arteriographien ermittelt. Fünf dieser Fälle hatten erhöhten Blutdruck mit typischen klinischen und röntgenologischen Befunde; in zwei Fällen mit typischer fibromuskulärer Hyperplasie wurden keine Zeichen von erhöhtem Blutdruck gefunden.

RÉSUMÉ

Les auteurs ont trouvé sept cas d'hyperplasie fibromusculaire des artères rénales sur une série de 338 angiographies rénales. Cinq de ces malades avaient une hypertension artérielle avec les signes cliniques et radiologiques caractéristiques, mais il n'y avait pas d'hypertension artérielle dans deux cas qui présentaient les signes angiographiques typiques de l'hyperplasie fibromusculaire.

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SELECTIVE CATHETERIZATION AND ANGIOGRAPHY OF BRONCHIAL ARTERIES IN DOG

by

BJORN NORDENSTROM

The difficulty in obtaining satisfactory filling of the bronchial arteries in thoracic aortography is probably largely due to the dilution of the contrast medium in the aorta and to the physical differences between it and the blood Small vessels arising from the aorta such as the intercostal and bronchial arteries are from their caliber and direction ideally adapted to the flow conditions of the blood When a contrast medium that is heavy in relation to the blood is introduced into the aorta it cannot however be expected to behave in the same way as the blood Contrast medium that has obtained a greater dynamic energy than the blood when it reaches the point of origin of a small artery will not readily diverge from the general blood stream This situation may indicate one of the important mechanisms that tend to inhibit contrast filling of the small aortic branches in thoracic aortography

Contrast medium was injected above a temporary occlusion of the thoracic aorta with balloon catheters in earlier experiments in order to master some of the difficulties in contrast filling of the bronchial vessels via the aorta (NORDENSTROM 1954) Quite small bronchial arteries could then be outlined, although

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Selective catheterization of the right seventh intercostal artery with injection of the bronchial branch of the intercostal artery. The barium emulsion had produced permanent capillary blocking of the branches of the capillary artery so that a positive contrast bronchogram of the walls of the upper and middle lobe bronchi was obtained.

the contrast losses via the collateral vessels to the aorta were considerable. The method could therefore not be used for more detailed studies of the shunt conditions in the lung. It was found possible, however, to implement an anatomical peculiarity in the dog, viz. that the right bronchial artery leaves the aorta as the first branch of the sixth intercostal artery in about 60 per cent of animals. The perfusion of contrast medium via the right sixth intercostal artery or a ramus muscularis from the latter resulted in the transmission of relatively large amounts of contrast medium to the right bronchial artery. Details of the arterial supply to the bronchi and pleura and the shunt conditions between the bronchial and pulmonary arteries could thus be recorded and studied in living dogs without recourse to thoracotomy.

Considerable advantages might accrue in experimental roentgen diagnostics and other studies of the bronchial vascular system, if direct catheterization of the bronchial arteries could be effected.

Selective catheterization with contrast injection into the right seventh intercostal artery in a dog weighing 20 kg is shown in the accompanying illustration. The animal was examined under intraperitoneal nembutal narcosis. A roentgen opaque polythene catheter the point of which had been drawn out to a length of 4 cm and well curved was introduced into a femoral artery. The catheter was moved systematically up and down towards the posterior wall of the aorta under fluoroscopic control until the tip could be introduced into an intercostal artery; as soon as the artery was catheterized a small amount of Urografin 60 % was injected. The catheterization of the seventh intercostal artery in this animal resulted in contrast filling of the right bronchial artery. Since it was proved that the bronchial artery could be reached in this way, the water soluble medium was exchanged for a suspension of barium sulphate in physiologic saline and the latter injected in order to bring about capillary blocking of the bronchial arteries. A rather large amount of the Urografin then injected leaked to the aorta but the permanent capillary blocking of the bronchial arterial branches resulted in a 'positive contrast bronchogram' of the upper and middle lobe bronchi (see figure).

Discussion

The bronchial vessels belong to one of the vascular regions about which relatively little is known, probably due to the difficulty of access. Selective catheterization with contrast filling of these vessels appears, however, to open up a possibility of acquiring further knowledge of the morphology and function of this system in living animals with the thorax intact.

SUMMARY

A technique for the selective catheterization and contrast injection of the bronchial arteries in the dog is described. Experimental capillary blocking of the arterial branches made it possible to outline the walls of the bronchi with contrast medium.

ZUSAMMENFASSUNG

Eine Methode für die selektive Katheterisierung und Kontrasteinspritzung der Bronchialarterien des Hundes wird beschrieben. Durch experimentelle kapillare Blockierung der Verzweigungen der Bronchialarterie war es möglich, die Bronchialwand mit dem Kontrastmittel darzustellen.



Selective catheterization of the right seventh intercostal artery with injection of the bronchial branch of the intercostal artery. The barium emulsion had produced permanent capillary blocking of the branches of the capillary artery so that a "positive contrast bronchogram" of the walls of the upper and middle lobe bronchi was obtained.

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Considerable advantages might accrue in experimental roentgen diagnostics and other studies of the bronchial vascular system if direct catheterization of the bronchial arteries could be effected.

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PHLEBOGRAPHY IN VARICOCELE SCROTI

by

N E AHLBERG O BARTLEY, N CHIDEKEL and Å FRITJOFSSON

The veins of the spermatic cord are abnormally wide and tortuous in both primary and secondary varicocele The primary form is by far the more common among the causes of secondary varicocele are renal tumor (SPITTEL et coll 1959) hydronephrosis (WHITE 1914) aberrant renal artery (CAMPBELL 1914) and arching of the spermatic artery over the renal vein (NOTKOVICH 1955) The pathogenesis of primary varicocele has not been clarified BRODNY et coll (1955) stated that it most often starts at puberty and occurs in about 10 % of the male population on the left side in about 90 % bilaterally in 8 % and on the right side in 2 % of these The clinical importance and treatment of the condition as well as the pathogenesis are dealt with in another report by the present authors (FRITJOFSSON et coll)

The scrotal veins may be considered as lying in two groups a deep group and a surface network group (JAVERT & CLARK 1944) The deep system comprises the pampiniform plexus the internal and external spermatic veins and the ductus deferens veins The pampiniform plexus consists of a network of veins which originate in the testis and epididymis it is drained by the three afore mentioned larger vessels The internal spermatic vein passes through the

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RÉSUMÉ

Description d une technique de cathétérisme électif et d injection de contraste dans les artères bronchiques du chien Le blocage expérimental des capillaires des branches des artères bronchiques a permis de rendre visibles par le moyen de contraste les parois des bronches

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inguinal canal into the retroperitoneal space, the left internal spermatic vein opens into the left renal vein, and the right internal spermatic vein usually terminates in the inferior vena cava below the right renal vein Communicating veins on both sides connect the middle and upper parts of the internal spermatic vein with the veins of the lumbar plexus, the renal capsule, the ureter and the subperitoneal connective tissue (TUFFIER & LEJARS 1891) The present authors (AHLBERG et coll (b), to be publ) have noted that the internal spermatic vein may be duplicated in its entire abdominal course The external spermatic vein passes through the inguinal canal and empties into the inferior epigastric vein near the termination of the latter at the femoral vein The ductus deferens veins follow the ductus deferens through the inguinal canal and empty via the vesical veins into the internal iliac vein The deep venous system communicates in the scrotum and in the external inguinal ring with the superficial venous system which consists of the anterior and posterior scrotal veins The former drains into the femoral vein, and the latter into the external iliac vein Considerable variation in the termination of these small veins may occur

In an investigation of male autopsy material we examined the valves in the cranial portion of the internal spermatic veins on both sides (AHLBERG et coll (a), to be publ) Valves were absent on the left side in 40 % of the cases and on the right side in 23 % of the cases Incompetent valves occurred on the left side in 10 % of the cases while the figure for the right side was 16 % The left internal spermatic vein always ended in the renal vein while the right internal spermatic vein terminated in the renal vein in only 10 % of cases and in the inferior vena cava in the remainder Anatomical conditions permitting retrograde flow of the blood thus existed in this material in about half the number of cases on the left side and in almost half on the right

ISTOMIN (1909) and SMIRNOFF (1929) found valves in the middle and caudal portions of the internal spermatic vein in about one fourth of their autopsy cases The present authors did not study the occurrence of valves at these levels of the internal spermatic vein in the autopsy specimens

The suggestion was made in an earlier work (AHLBERG, BARTLEY & CHIDEKEL 1965a) that a relation may exist between retrograde flow in the internal spermatic vein and the occurrence of varicocele scroti Selective phlebography of the renal veins has therefore been carried out and the findings in cases with and without varicocele scroti compared The technique employed has not been described earlier in roentgenologic studies of varicocele scroti At operation on varicocele, however studies have been made of the venous drainage after contrast injection into either the veins of the pampiniform plexus or the inguinal part of the internal spermatic vein (COTRIM & BARBOSA DE BARROS 1941,

BRODNY et coll 1955 LANE 1955 GOSFAY 1959 LEGER 1959 MOUCHA 1960 SCOTT 1960 VASSILEV 1962)

The technique we used for catheterization of the renal veins is the one described by HELANDER et coll (1958) for use in dogs It has also been applied to man by among others EDVALL (1958), HELANDER & LINDBOM (1960) and FUCHS (1963)

Methods The femoral vein was percutaneously punctured under local anesthesia usually on the side on which the renal phlebography was to be performed and a No 205 Odman catheter was introduced via the inferior vena cava into the renal vein under monitor screen control Prior to insertion the end of the catheter had been curved and three side holes within 1 cm of the tip had been made Two contrast medium injections each of 40 ml Urografin 76 % were made with a Gidlund Elema syringe at a pressure of 2 kg / cm² All the patients were examined erect but eight patients including one of the controls were also investigated supine The region investigated extended from the renal vein to the upper part of the scrotum

After catheterization of the renal vein with the patient supine the patient was moved by means of the tilting table into the erect position The films were obtained p a at a FFD of 85 cm and were changed manually Two series of 35 × 35 cm films were necessary to cover the entire investigation region Careful shielding protected the gonads from direct radiation For the investigation of the renal vein and the cranial portion of the internal spermatic vein two exposures were made about 2 sec and 7 sec after the start of the first contrast injection while for the caudal portion three exposures at 5 sec, 10 sec and 20 sec after the second injection were routine In the course of the investigation a modification according to the afore mentioned technique was brought about

The investigations were generally simple to perform No complications were observed and it would appear that the investigations may be performed in out patients The patients were controlled one hour after the end of the investigation primarily for any possible bleeding The risk of thrombosis was reduced by ensuring that the patient was up and about as usual

Material The material comprised 35 patients 26 of whom had varicocele, or had been operated for this condition and 9 were controls without any history or signs of varicocele The average age in the varicocele group was 36 years (range 16 to 56 years) and for the controls 60 years (31 to 83 years) The investigation in the control group was performed on the left side

The clinical investigation in the varicocele group indicated that the varicocele was primary and located on the left side One patient also had a right



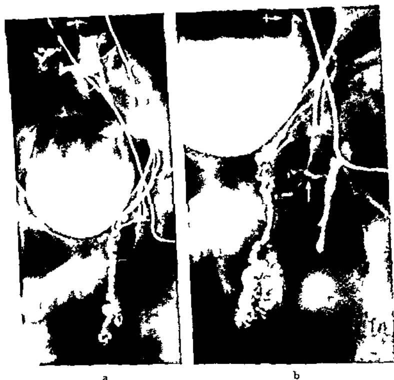
Fig. 1. Varicocele 2 sec after contrast injection into left renal vein. Internal spermatic vein filled in retrograde direction.

sided varicocele and was therefore investigated bilaterally although operation was performed only on the left side. Two patients were examined before as well as after operation so that the total number of investigations in the varicocele group was 29. The 28 examinations made on the left side were grouped as follows:

Group		*Number*
I	Unoperated varicocele	18
II	Operated, with persistent varicocele	4
III	Operated, without persistent varicocele	6

The investigations were not successful in 2 patients belonging to group I. In one of these the catheter could not be passed into the renal vein while in the other the contrast medium did not reach the opening of the internal spermatic vein due to the lack of a pressure syringe. The results are thus based on 35 left sided investigations of 33 patients.

Two patients in group II had been operated with local resection of the varicocele 10 and 9 years, respectively, before the investigation. In the other two patients the internal spermatic vein had been divided between ligatures 3 years and 2 months, respectively, before the examination.



a b

Fig 2 Varicocele a) At 16 sec after contrast injection Internal spermatic vein with two trunks at level of internal inguinal ring contrast filled and so is the varicocele b) At 94 sec Draining veins filled anterior scrotal vein (↑) opens into vena saphena magna and ductus deferens vein into vesical vein (←→)

Two patients of group III are also included in groups I and II respectively The postoperative investigation in one was carried out 7 months after operation and in the other 3 days after the second operation The other patients in group III were investigated 4 to 9 years following operation

Results

The entire length of the internal spermatic vein was contrast filled within 5 to 10 sec after the start of the contrast injection in groups I and II (Figs 1 and 2) In the first four patients in whom shielding of the testes was omitted even the varicocele was contrast filled (Fig 2) Exposures were made up to 100 sec after the injection in 18 of the 20 patients belonging to groups I and II and in all of them the veins draining the varicocele were demonstrated these were the anterior and posterior scrotal veins and the ductus deferens vein



Fig. 3



Fig. 4

Fig. 3. Varicocele. At 6.5 sec. The varicocele as well as the anterior scrotal veins draining bilaterally are filled.

Fig. 4. Varicocele persisting after operation. Four sec. after injection. Remaining trunk of internal spermatic vein and varicocele both filled. Pelvic veins filled from internal spermatic vein.

(Fig. 2b). In ten of the patients (Fig. 3), the right scrotal veins were also contrast filled.

Anastomoses were noted above the inguinal canal between the internal spermatic vein and the pelvic veins in two patients (Fig. 4). These were the patients investigated both before and after operation and the communicating veins were evident on both occasions.

No patient of group III or of the controls had complete retrograde contrast filling of the internal spermatic vein (Fig. 5). The vein was contrast filled on an average of 113 mm (range 100 to 230 mm) in group III. The corresponding figure for the control group was 59 mm (range 3 to 275 mm).

The veins of the lumbar plexus were filled from the renal vein in 18 patients of the total material (Figs. 5 and 6a).

The diameter of the internal spermatic vein was measured 10 mm caudal to its termination at the renal vein unless otherwise indicated. The internal spermatic vein was filled via a communicating vein from a branch of the renal



Fig 5 From the control group at 2 sec The upper part of the internal spermatic vein is contrast filled the suprarenal vein and the veins of the lumbar plexus filled from the renal vein.

vein in one patient of group I and one of group II The diameter of the spermatic vein in these two patients was measured just caudal to the entrance of this communication 15 and 25 mm respectively, below the renal vein In the control patients with competent valves the measurement was made immediately cranial to the valves The internal spermatic vein was duplicated all the way up to the renal vein in one patient who was excluded when the mean value for the diameter of the spermatic vein was estimated

In groups I and II the mean values for the diameter were identical i e 6 8 mm (ranges 4 to 11 mm and 5 to 8 mm respectively) The means for group III and the control group were 4 3 mm (range 3 to 6 mm) and 4 7 mm (range 3 to 7 mm) respectively In the statistical analysis with the t test S^2 was 4 58 for groups I + II 1 25 for group III and 1 75 for the controls Highly significant differences (t = 3 73 and 3 18 respectively) were apparent between the combined group (I + II) and group III or the control group no significant difference was found between group III and the control group Thus patients with unoperated varicocele or with the condition persisting after operation had significantly wider internal spermatic veins compared with those successfully operated and the controls The significant difference in diameter between the combined group and group III may indicate that the vein s diameter diminishes after successful operation Of the two patients examined before as well as after operation the diameter in one was the same three days after



Fig 6 Varicocele a) At 2 sec Upper part of internal spermatic vein (←) filled from the main *trunk of the renal vein and lower wider part from a branch (←+) of the renal vein b) At 15 sec* The competent valves (←) in the upper part the of internal spermatic vein are visible

operation while in the other the width had been halved during the 7 months following the operation The decrease in the diameter was thus probably gradual

An investigation of the number of trunks of the internal spermatic vein at the level of the internal inguinal ring indicated that five of the 16 patients in group I had two trunks at this level (Fig 2a) and one had three This was probably also true in two patients of group II in whom the varicocele persisted even though an internal spermatic vein had been divided between ligatures Thus, in about one third of the patients with varicocele more than one trunk of the internal spermatic vein existed at the internal inguinal ring

Competent valves were demonstrated in the cranial portion of the spermatic vein in two patients with varicocele (Fig 6) As already mentioned, the internal spermatic vein was contrast filled in a retrograde direction via a communication from a branch of the renal vein in both instances Valves were not observed in the internal spermatic vein in any of the other varicocele patients On the other hand, competent valves were demonstrated in five of the controls These valves were situated within 10 cm of the renal vein

The results obtained with the varicocele patients in the supine position compared to the erect were somewhat different In only two of the 7 patients investigated supine did the entire spermatic vein fill with contrast medium In the other five patients contrast filling of only the cranial portion of the internal spermatic vein was noted

In the case with right sided varicocele, the right internal spermatic vein was contrast filled for its entire length and a small varicocele was also outlined The diameter of the right internal spermatic vein was 3 mm The vein opened into the medial end of the right renal vein

Discussion

Varicocele scroti seldom causes disturbing local symptoms It has been demonstrated however that the condition is often combined with subfertility (TULLOCH 1952 RUSSEL 1954 SCOTT 1958 FRITJOFSSON, to be publ) This fact has increased its importance and its treatment

In all of the patients with varicocele the gonadal vein throughout its entire length was contrast filled in a retrograde direction when the investigation was performed with the subject erect Since this was not a constant finding in the supine position the investigation must be carried out with the patient erect Even if the number of films is reduced and the gonads protected from direct radiation the patient is nevertheless exposed to a certain though small gonadal dose Division of the internal spermatic vein between ligatures usually gives very satisfactory results and it may therefore be questioned whether the investigation should be routinely performed before operation in patients with varicocele The anatomy may be more or less deranged in varicocele patients previously operated on in the inguinal region either for the varicocele or for any other condition Phlebography is then indicated as it affords valuable information concerning the venous anatomy and therefore facilitates further operative treatment

The results of the investigation from many aspects revealed significant differences between patients with and without varicocele The internal spermatic vein in the former group was completely contrast filled in a retrograde direction this was not apparent in the latter Furthermore the mean values for the diameter of the vein differed significantly between the two groups The veins were wider in the patients with varicocele However a small diameter does not necessarily exclude the presence of varicocele while a large diameter makes the diagnosis probable The internal spermatic vein often consists of several trunks at the level of the internal inguinal ring When treating the varicocele with ligation of the internal spermatic vein at that level this fact deserves due attention This is illustrated by the two patients in

whom the varicocele persisted despite internal spermatic vein division between ligatures Roentgenologic examination in both instances disclosed a *persistent* trunk of the *internal spermatic* vein filled in a retrograde direction This trunk was *tied off* at re operation and the varicocele disappeared

It is maintained in the literature (LANE 1955) that varicocele scroti is always caused by incompetent valves in the cranial portion of the internal spermatic vein *This does not* appear to be true Retrograde flow and varicocele *can occur* despite competent valves because the blood can bypass the valves via communicating veins entering the internal spermatic vein caudal to the valves

Many different surgical methods have been employed *in the treatment of* varicocele In regard to the observed retrograde passage, which only occurred in patients with varicocele, ligation of the internal spermatic vein may be adequate The anatomical differences in the course of the right and left gonadal veins depend on the embryologic development as described in another report (AHLBERG *et coll* (b), *to be publ*) The right gonadal vein usually empties into the inferior vena cava, but drainage into the right renal vein occurs in about 10 % of the male population The right gonadal vein may even empty into the left renal vein, which has been observed by DZIALLAS (1947) as well as by AHLBERG, BARTLEY, CHIDEKEL & WAHLQVIST From a practical *point of view* this rare condition would mean that the roentgenologic demonstration of a right sided varicocele might actually require catheterization of the left renal vein

SUMMARY

Percutaneous selective renal phlebography was performed in the erect position in 26 patients with varicocele or who had been operated on for this condition as well as in 9 control The significance of retrograde filling and an increase in the width of the internal spermatic vein is discussed

ZUSAMMENFASSUNG

An 26 Patienten die an Varicocele litten oder hierfur operiert worden waren wurde die selektive renale Venographie im Stehen vorgenommen ebenso wurde dieselbe Untersuchung an 9 normalen Personen ausgefuhrt Die Wichtigkeit einer retrograden Füllung der Vena spermatica interna und deren abnormen Weite wird beschrieben

RÉSUMÉ

Les auteurs ont fait une phlébographie rénale sélective percutanée en position debout à 26 malades porteurs de varicocele ou qui avaient été opérés pour cette affection ainsi qu'à 9 sujets témoins Ils examinent la signification du remplissage rétrograde et de l'augmentation de calibre de la veine spermatique interne

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GYNECOGRAPHY IN DIAGNOSIS AND TREATMENT EVALUATION IN TURNER'S SYNDROME

Report of 3 cases

by

GOSTA SWAHN ALLAN LUNDERQUIST and STURE RAFSTEDT

Recent observations suggest that it may be time to revise the definition of Turner s syndrome TURNER (1938) based his original description of the syn drome entirely on morphologic phenomena infantilism (dwarfness of stature underdevelopment of the secondary sex characteristics), pterygium colli and cubitus valgus in an individual of female phenotype The term gonadal dysgenesia was introduced in 1942 (ref 8, 16 17), and chromosomal aberra tions were first described in 1959 (ref 6 7, 14) Like the malformations however these new components were neither sufficiently regular nor uniform to serve as a basis for a generally valid definition of Turner s syndrome, one that must still be regarded as vague Dwarfism seems to be a fairly regular component LINDSTEN (1963) therefore suggested the following criteria as hallmarks of the condition (1) dwarfism (essential) (2) gonadal dysgenesia (common but not essential) (3) malformations (common but not essential),

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(4) chromosomal aberrations (various non specific normal XX karyotype) (ref 1, 2, 10)

An examination for morphologic abnormalities of the ovaries occupies a central position in the investigation of Turner s syndrome, formerly usually performed by explorative laparotomy or e g culdoscopy with puncture of the posterior fornix This latter method may, however well be replaced by gynecography (roentgen examination of the pelvis after its insufflation with air) which will reveal the size of ovaries if present, with much less inconvenience to the patient Gynecography will also demonstrate the size and shape of the uterus, in complete infantilism the uterus is represented only by a slight central thickening of the ligamentum latum uteri

Various hormones have been tried in the treatment of Turner s syndrome, viz gonadotrophin somatotrophic, androgenic and oestrogenic hormones and the thyroid hormone (ref 4, 5 9) Of these hormones only oestrogens have proved to have a favourable and definite effect manifested mainly by the response of the secondary sex characteristics An influence on stature has also been reported but since treatment was usually started during puberty it is not certain whether the growth recorded was due entirely to the oestrogen therapy There is however, now a tendency to believe that dwarfism like malformations is due to genetic factors and cannot therefore at least theoretically, be affected by oestrogen therapy

The effect of oestrogen therapy manifests itself in various ways For example, the originally high urinary gonadotrophin level falls markedly owing to the inhibitory effect of the oestrogens on the hypophysis The effect of oestrogens is reflected in the epithelial cells in vaginal smears The external sex characteristics that develop are associated with menstruation which can be induced at regular intervals by cyclic administration of the hormone

The effect of hormone therapy on uterine growth may be demonstrated objectively by gynecography before and during treatment This is exemplified in the following three cases

Case reports

Case 1 No family history of dwarfism primary sterility or endocrine disease Mother healthy during pregnancy no special treatment or hormone therapy parturition uncomplicated birth weight 2 900 g post partum normal no oedema At the age of 7 years the girl s height was 106 cm and at 10 years it was 120 cm At 9 years the child was given 8 injections of gonadotrophin without any obvious effect

The girl was examined at our hospital at the age of 14 years with the following results Dwarf stature height 128 cm

Malformations Short broad neck with slight pterygium colli low posterior hair line margin marked cubitus valgus low broad chest nipples wide apart Skeletal malformations consisted



a



b



c

Fig 1 Case 1 a) No uterus left ovary rudimentary right ovary not demonstrable b) After 13 months Uterus though small is now evident both ovaries can be recognized but are still rudimentary as at previous examination no signs of growth c) After 21 months Uterus now almost normal in size ovaries of same size as at previous examination



F g 3 Case 3 a) No uterus or ovar es evident b) After 6 months Uterus almost normal n size left ovary rud mentary no ovary on right s de

parturition was uncomplicated birth weight 2 450 g Post partum there was oedematous swelling of hands and feet which persisted during the first year of life retarded growth of stature during pre school age but normal mental development

When first seen by us the child was 13 1/2 years old and examination then revealed the following conditions Dwarf stature height 129 5 cm

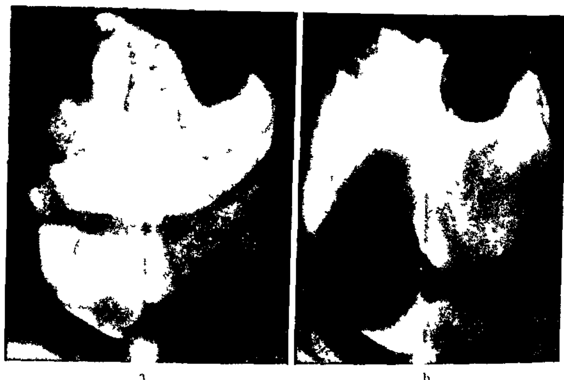
Malformations Short broad neck with pteryg um colli low posterior hair line margin moderate cubitus valgus chest broad nipples w de apart No skeletal abnormalities except reduced gamma angle of cranium No signs of renal malformation or aortic coarctation

Ovarian dysgen sia Female phenotype without signs of oestrogen effect no secondary sex characteristics no menstruation FSH< 40 M U /24 hrs oestrogen < 25 M U /24 hrs Vaginal smear showed no oestrogen effect

Gynecography on 7 April see Fig 2a

Chromosomal aberrations Karyotype a complicated mosaic of following appearance XX/XO/XXX/XX isoX/XXX isoX In accordance with this karyotype both chromatin negative and chromatin positive cells with one and two sex chromatin bodies respectively were evident Cell with three sex chromat n bodies corresponding to the cells with XXX isoX karyotype should also have been demonstrable that they were not may be explained by the fact that these cells were so few in number This pattern has as far as we know never before been seen in Turner s syndrome Readers interested in further details are referred to a paper by SANDAHL & SWAHN (1964)

Treatment Oral Stilbol 0 5 mg per diem was given from 10 April 1964 Moderate development of secondary sex characteristics occurred Vaginal bleeding in October 1964 vaginal



a b

Fig 2 Case 2 a) No uterus the plica lata appears somewhat broader on the right side no ovaries evident b) After 6 months Uterus of normal size to right in small pelvis no ovaries present

of increased growth of medial femoral condyle and depression of medial tibial condyle cubitus valgus short ulna and curved radius distal articular surface of radius oblique fourth metacarpal abnormally short in both hands gamma angle of cranium decreased

Aortography Slight aortic coarctation without collaterals

Nephro angiography Horse shoe kidney

Ovarian dysgenesia Female phenotype without signs of effect of oestrogen no secondary sex characteristics no menstruation FSH < 25 M U /24 hrs oestrogen < 25 M U /24 hrs Vaginal smear showed *no signs of oestrogen effect*

Gynecography on 29 January 1964 see Fig 1a

Chromosomal aberrations Karyotype XO sex chromatin negative

Treatment From 4 March 1963 the patient was given 0 5 mg oral Stilbol a day and from 24 December 1963 the same dose but at 3 week intervals In October 1964 the dose was increased to 1 mg a day Marked development of secondary sex characteristics occurred with vaginal bleedings from 23 December 1963 vaginal smears indicated response of epithelial cells to oestrogen FSH < 10 M U /24 hrs and oestrogen about 200 M U /24 hrs Growth of stature 6 cm during last 22 months

Gynecography on 24 February (Fig 1b) and 30 December 1964 (Fig 1c) revealed marked growth of the uterus

Case 2 Retardation of physical development of patient s sister who was of normal karyotype XX however No other instance of dwarfism primary sterility or endocrine disorder in family During pregnancy mother was healthy and had received no special medication

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smears indicated a moderate oestrogen effect FSH < 10 M U /24 hrs, oestrogen about 200 M U /24 hrs Growth in stature 1 5 cm in 7 months

Gynecography on 22 October 1964 disclosed marked growth of the uterus (Fig 2b)

Case 3 No dwarfism primary sterility or endocrine disorder in the family During pregnancy the mother was healthy and received no special treatment nor hormonal therapy parturition was uncomplicated birth weight 2 800 g at birth the child appeared normal with no signs of oedema Physical growth was markedly retarded during pre school age but mental development was normal

When first seen by us the child was 14 years old Examination then revealed the following conditions Dwarfism of stature, height 125 cm

Malformations Marked cubitus valgus and broad 'shield like chest and short neck Skeletal abnormalities consisted of marked cubitus valgus but no abnormal angulation of articular surfaces No other skeletal malformations, no signs of aortic coarctation or renal malformations

Chromosomal aberrations Karyotype XO Sex chromatin negative

Treatment Oral Stilbol 0 5 mg per diem was given from 25 March 1964 Moderate development of secondary sex characteristics occurred with vaginal bleeding from 3 August 1964 Vaginal smears indicated oestrogenic effect FSH < 10 M U /24 hrs oestrogen about 200 M U /24 hrs Growth in stature 3 5 cm during 9 months treatment

Gynecography on 23 October 1964 revealed that the uterus had become almost normal in size since the previous examination (Fig 3b)

SUMMARY

The difficulty in formulating an adequate definition of Turner s syndrome is discussed Three cases illustrate the value of gynecography in the morphologic diagnosis of ovarian dysgenesia and in the evaluation of the effect of oestrogen treatment on the growth of the uterus

ZUSAMMENFASSUNG

Die Schwierigkeiten einer zutreffenden Definition des Turner Syndromes werden erörtert Drei Fälle beweisen den Wert der Gynäkographie für die morphologische Diagnose der ovariellen Entwicklungsstörung und für die Beurteilung der Wirkung der Östrogenbehandlung, soweit sie das Wachstum des Uterus beeinflusst

RÉSUMÉ

L auteur examine les difficultés qu il y a à formuler une définition adéquate du syndrome de Turner Trois cas illustrent l intérêt de la gynécographie pour le diagnostic morphologique de la dysgénésie ovarienne et pour l appréciation de l effet du traitement oestrogénique sur la croissance de l utérus

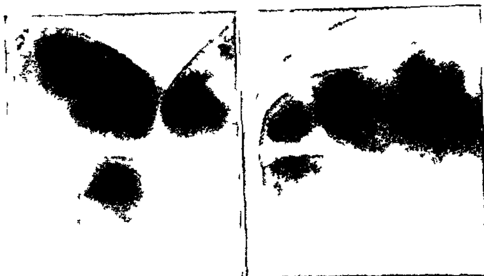


Fig 1 Moderate proctitis in a male aged 19 Barium enema Ordinary length and smooth contours but reduced distensional capacity and absence of folds of rectum retrorectal soft tissue space of normal size Moderate changes were present at rectoscopy Biopsy see fig 3

therefore considered it would be of value to carry out a comparative investigation of the findings obtained by barium enema examinations rectoscopy and biopsy in subjects with and without symptoms referable to the rectum

Methods The evaluation of each case included a routine clinical examination, a barium enema rectoscopy and rectal biopsy These procedures were accomplished within 9 days or less generally within 2 to 6 days and the condition of the patients did not change significantly during the time interval The roentgenologic rectoscopic and microscopic studies were carried out without knowledge of the findings at the other examinations

The roentgen examinations of the rectum and colon were performed with conventional techniques The rectum and sigmoid colon were examined in the supine oblique prone oblique, and lateral positions with final survey roentgenograms before and after evacuation At least one of the oblique views together with the lateral view were exposed as the barium was run in so as to ascertain the degree of distension of the bowel Particular attention was paid to the length distension primary folds mucosal relief and contours of the rectum and sigmoid colon and to the retrorectal soft tissue space

The rectoscope was introduced to a distance of 15 to 25 cm from the external anal orifice and rectum and lower part of the sigmoid colon were inspected

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CORRELATION OF FINDINGS AT BARIUM ENEMA EXAMINATION, RECTOSCOPY AND BIOPSY OF RECTUM

by

N P G EDLING, O EKLÖF, S KISTNER and B LAGERLÖF

Rectoscopy is considered to be the diagnostic method of choice in evaluating rectal disease, corresponding to the significance of the barium enema in the detection of changes in the colon Some clinicians tend, however, to rely almost entirely on the barium enema findings and restrict the clinical examinations of the rectum Rectal biopsy has for the most part been confined to cases in which polyps or tumours were probable at rectoscopy or barium enema, but recently it has been employed for assessing inflammatory changes in the rectal wall

The clinical condition of the patient and the findings at rectoscopy have been correlated with the morphologic appearances of the mucosa and submucosa in inflammatory disease of the rectum (LEVINE et coll 1951, TRUELOVE et coll 1955, LUMB & PROTHEROE 1955, TRUELOVE & RICHARDS 1956, HEINKEL et coll 1960 COOK et coll 1961, DICK & GRAYSON 1961, MATTS 1961, HEINKEL 1962, FLICK et coll 1962) The literature on correlation of the roentgenologic findings with those obtained at rectoscopy and biopsy is however scanty despite the great number of barium examinations performed It appears that such an investigation has been performed only by COOK et coll The present authors

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Fig 3 Same case as in fig 1 Biopsy of rectal wall Ordinary thickness of mucosa but irregular and wide crypts inflammatory infiltrates increased but no actual abscess formation present no surface ulceration



Fig 4 Same case as in fig 2 Biopsy of rectal wall Ordinary thickness of mucosa but surface ulcerated very irregular crypts and reactive epithelial cells marked inflammatory cell infiltration with small abscess formations inflammatory infiltrates also present in the muscularis mucosa

The comparative study of findings at the examinations by the three methods included normal and inflammatory features melanosis and some incidental polyps The inflammatory wall changes were described only as moderate and marked (Figs 1 to 4)

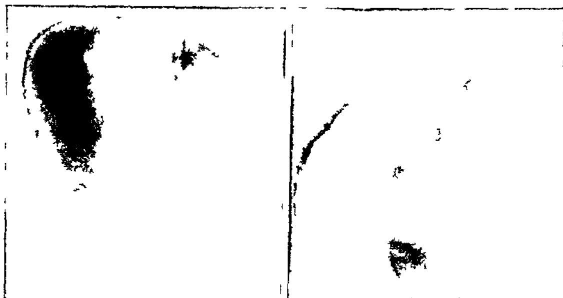


Fig 2 Marked proctitis in male aged 65 Barium enema Marked shortening slightly irregular contours reduced distensional capacity and absence of folds of rectum retrorectal soft tissue space considerably increased Marked changes evident at rectoscopy Biopsy see fig 4

The colour and smoothness of the mucosa, as well as the presence of edema, mucus, abscesses, erosions and polyps were carefully noted

Biopsy forceps were introduced when the rectoscope was 10 cm from the external anal orifice, and a specimen was resected from the anterior wall of the rectum Additional specimens were also obtained when local changes, such as polyps or infiltrations, were noted in other parts The biopsy caused slight bleeding, which usually stopped after the application of a 0 25 % suspension of colloidal silver The specimens, which generally contained mucosa, muscularis mucosa and submucosa, were fixed in 10 % formaldehyde, suitably prepared and stained with haematoxylin eosin and by the van Gieson method The general appearance and the thickness of the mucosa were examined microscopically, and any disturbance of the general architecture was evaluated Any inflammatory infiltrates in addition to sites and size of lymphocytic foci, were recorded Particular attention was paid to the presence of edema, fibrosis and ulceration of the surface

Material The series comprises 46 cases Twelve of these had no histories of symptoms referable to the colon or rectum, 10 had ulcerative colitis, 18 vague disorders of the colon or rectum and 3 cases had atypical abdominal pain There were 2 cases of cancer of the transverse and descending colon, respectively, and one of melanosis of the sigmoid colon and rectum

Table 1

Distribution of cases according to findings at barium enema and rectoscopy

Barium enema	Number of cases	Rectoscopy			
		Normal	Moderate infl	Marked infl	Melanosis
Normal	16	11	3	1	1
Moderate infl	24	11	13		
Marked infl	6		2	4	
	46	22	18	5	1

One case with one polyp One case with three polyps

Table 2

Distribution of cases according to findings at barium enema and biopsy

Barium enema	Number of cases	Biopsy			
		Normal	Moderate infl	Marked infl	Melanosis
Normal	16	8	7		1
Moderate infl	24	8	15	1	
Marked infl	6		1	5	
	46	16	23	6	1

Table 3

Distribution of cases according to findings at rectoscopy and biopsy

Rectoscopy	Number of cases	Biopsy			
		Normal	Moderate infl	Marked infl	Melanosis
Normal	22	13	9		
Moderate infl	18	3	13	2	
Marked infl	5		1	4	
Melanosis	1				1
	46	16	23	6	1

Results

The *distribution of cases according to findings at the barium enema examination and at rectoscopy* is given in Table 1 The majority of the 16 cases with normal barium enemas were also of normal rectoscopic appearance A case with contrast filling of very fine smoothly contoured cavities in the rectal wall was included among the normal cases, these unusual appearances were considered to represent normal intestinal crypts However, in four roentgenologically normal cases rectoscopy revealed inflammatory changes, in one of them rather marked, and in addition one case had melanosis, a finding not demonstrable roentgenologically Rectoscopy revealed moderate inflammatory changes in half the number of cases but no abnormality in the other half of the 24 cases in which the roentgen examinations suggested moderate proctitis Roentgenologic evidence of marked inflammatory changes in 6 cases corresponded to moderate and marked changes at rectoscopy

The cases are correlated according to the barium enema and biopsy findings in Table 2 *Of the 16 cases with normal roentgen appearances* eight had at biopsy normal findings and the remainder moderate inflammatory changes, the case with contrast filling of the crypts presented no evidence of abnormality and *the one case of melanosis diagnosed by rectoscopy was confirmed* One third of the 24 cases with moderate inflammatory changes at the roentgen examination were considered normal and two thirds had signs of inflammatory changes at biopsy, of the latter group one had *marked* and the rest only moderate changes Of 6 cases with marked inflammatory changes diagnosed roentgenologically one was found to have moderate and the remainder marked changes at biopsy

Correlation of the rectoscopic and biopsy findings is presented in Table 3 Of the 22 cases with normal appearances at rectoscopy more than half were found to be normal at biopsy while the remainder had moderate inflammatory changes Moderate inflammatory changes in 18 cases at rectoscopy were in the main confirmed by biopsy The microscopic findings were, however, normal in 3 cases, and marked inflammatory changes were present in 2 cases Marked inflammatory changes at rectoscopy in 5 cases corresponded to 4 cases with marked changes and one with moderate changes the remaining case was the one with melanosis

Small polyps, 1 to 3 in number, were observed in 3 cases, in addition to the above findings All were revealed by rectoscopy, and one also by roentgen examination Microscopy of the polyps disclosed slight atypism but no malignancy, the barium enema examination revealed a rough and irregular mucous membrane relief in one of the cases

The distensibility of rectum seems difficult to judge since the individual variations are great Several projections including films obtained during the run in of the barium to demonstrate maximal distension of the rectum, are of particular value and will help in producing constant findings The authors recommend a cautious attitude towards a diagnosis based only on reduced rectal distensibility, against the advice given by FARIBAULT et coll (1962) The assessment of length may also be of doubtful value The mucosal relief can be studied only when the rectum is fully contracted after the evacuation of the enema An increase in the retrorectal soft tissue space indicates a pathologic condition (RUDHE 1960 EDLING & EKLOF 1963 CRISPIN & FRY 1963) Further information may also sometimes be obtained by comparing the different features with films from previous examinations

The findings in each one of the separate examinations included in the present investigation were evaluated without knowledge of those in the others The results indicate the necessity of different types of examination for attaining a proper diagnosis in diseases of the rectum In no case with obscure clinical signs would it be possible to attain a definitive diagnosis by any one method alone A barium enema examination and rectoscopy are always required in these cases and if unrewarding should be supplemented with biopsy

SUMMARY

The findings at barium enema examination rectoscopy and biopsy in a series of 46 cases with and without inflammatory disease of the rectum are compared and discussed Full correlation between the results was not always attained The study indicated the difficulty of obtaining an unequivocal diagnosis by one of the methods alone

ZUSAMMENFASSUNG

Die Röntgenbefunde nach Bariumeinlauf Rektoskopie und Biopsie in einer Serie von 46 Fallen mit und ohne entzundliche Veranderung des Rektums werden verglichen und beschrieben Die Resultate konnten nicht immer in Einklang gebracht werden Die Arbeit zeigt die Schwierigkeit mit einer einzigen Methode zu bestimmten Schlussen zu kommen

RÉSUMÉ

Les auteurs ont étudié et comparé les résultats du lavement baryté de la rectoscopie et de la biopsie sur une série de 46 cas dont certains présentaient une affection inflammatoire du rectum Ils n ont pas toujours constaté une concordance complète des résultats de ces examens Ce travail montre la difficulté d obtenir un diagnostic certain par une seule de ces méthodes

Discussion

A comparison of the diagnostic results of barium enema examination, rectoscopy and biopsy indicates that they are not wholly consistent The time interval between roentgen examination and rectoscopy in the series did not exceed 9 days As the clinical conditions of the patients were considered to be unchanged it seems improbable that the time interval could have played any role in the different findings The absence of full correlation of the features assessed by the three methods may be explained in other ways

Proper cleansing of the bowel must take place prior to a barium enema and rectoscopy, this must be performed carefully in order to avoid irritation of the bowel but still be effective Rectal irritation following cleansing may influence the results of examinations by causing variations in appearance of the rectum that may be difficult to evaluate

The characteristics of the three methods are very different The barium enema examination reveals the rectum in its entire length in various projections, rectoscopy, and biopsy, particularly, depict circumscribed areas The roentgen examination affords general information about the distensibility, length and main folds of the rectum, and is of importance in assessing the rectal contours and mucosal relief In addition, the retrorectal space may be examined for perirectal changes, and the remainder of the large bowel can be included in the same examination Rectoscopy enables the various parts of the mucosal surface to be inspected, and any secretion, bleeding or ulceration to be detected Microscopy alone permits the morphology of the rectal wall, even if only a very small part, to be determined

The opportunity for re scrutinizing films and biopsy specimens naturally always exists, but rectoscopy unless supplemented with photography must necessarily be subject to observer variations

Early inflammatory changes may be rather patchy and probably cannot be diagnosed by an enema Again, healing inflammatory changes of the rectum will be disclosed by biopsy but will not be evident at a barium enema examination or at rectoscopy

Classification of the different features in the series was limited to normal findings and moderate or marked inflammatory changes Despite this broad categorization the different groups were not sharply demarcated and there was often difficulty in judging to which group a given case belonged Moderate changes were by all the methods more difficult to distinguish from the normal than from the marked changes Cases with only slight changes were included in the moderate group, this occurred particularly where microscopy revealed only slight increase in inflammatory infiltrates

FROM THE ROENTGEN DEPARTMENT, CENTRALLASARETTET HALMSTAD, SWEDEN

INTESTINAL ENDOMETRIOSIS

by

BENGT LILJA and FRANS PROBST

Endometriosis because of its sex limited nature its responsiveness to hormonal treatment its variable location and its infiltrative though largely benign mode of growth offers many interesting aspects The roentgen examination although often of great significance in diagnosis may also give rise to difficult problems in the differential diagnosis especially from malignant tumours

The condition has been encountered in 8 % to 15 % of all menstruant women (HAWTHORNE KIMBROUGH & DAVIS 1951) SCOTT & TELINDE (1950) in a large series of cases noted endometriosis in 5 6 % of their gynecologic laparotomies while SUTLER & ARBOR (1947) mentioned an incidence of 10 % to 20 % and MEIGS (1948) gave a similar high figure

In the intrauterine or internal form of endometriosis — adenomyosis — hysterosalpingography often produces typical roentgenographic appearances (ÅKERLUND 1943) the uterine wall is irregular with evidence of small diverticular or lacunar bulges

The external form in which the uterine tissue lies outside the uterus is usually seen in the lower part of the abdomen but its location and extent vary considerably The ovaries are involved in 80 % of cases (SCOTT & TELINDE

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1 000 cases reviewed by HENRIKSEN (1955) the youngest patient was 16 and the oldest 83

The clinical signs and symptoms of endometriosis vary considerably Dysmenorrhea is common and usually lasts for the whole period in this it differs from spasmodic dysmenorrhea which is usually present only during the first few days (JEFFCOATE 1957) Meno- and metrorrhagia have been observed Abdominal pain of varying severity sometimes imitating acute or subacute appendicitis may arise at different sites as well as deep pelvic pain radiating out towards the sacrum In other cases (23 % according to HENRIKSEN 1955) the complaint is not associated with dysmenorrhea or pain Dyspareunia is reported in many cases Sterility is common occurring in roughly a third of cases according to MACAFEE & GREER (1960) SCOTT & TELINDE (1950) gave a similar figure Not infrequently the condition causes no symptoms and is only discovered incidentally The extent of the endometriotic changes in the pelvis by no means always corresponds to the severity of the clinical symptoms Extensive changes with hard edged adhesions may cause practically no discomfort and vice versa

Endometriosis is progressive during the reproductive period and diminishes after the menopause this also applies to intestinal endometriosis and is a factor of great prognostic and therapeutic value In a few cases however the condition may continue to progress after the menopause

When endometriosis occurs in the intestinal wall it is located mainly in the muscular coat which then becomes hypertrophic and disintegrated it is also found in the subserosa and sometimes at the base of the submucosa Infiltration into the mucosa is rare This change is not identical with the fibrous shrivelling of the anterior wall at the rectosigmoid junction described by THEANDER & WEHLIN (1961) in connection with pelvic endometriosis

Intestinal endometriosis may occur as an isolated phenomenon (MAYO & MILLER 1940 16 out of 38 cases RYLEY 1956 13 out of 19 cases) or together with other manifestations of the condition It was found in 35 (4 %) out of 848 cases investigated by SUTLER & APBOR (1947) and in 12 % in another material comprising over 7 000 cases of endometriosis assembled from various publications (MACAFEE & GREER 1960) COLCOCK & LAMPHIER (1950) reported an incidence of 18 % among 213 surgically treated endometriosis cases and of 39 cases with intestinal localization fourteen had more or less severe stenosis MACAFEE & GREEP (1960) noted signs of stenosis in 27 % of 371 cases assembled from the literature

In a series of 497 cases studied by MASSON (1945) the distribution in the intestines was as follows sigmoid flexure rectosigmoid region, rectum 72 % rectovaginal septum 13 % small intestine 7 % cecum 4 % appendix 3 %

1950) The growths are diffusely scattered in the true pelvis and commonly lie on the surface of the uterus and tubes as well as in the posterior recess in about a third of cases The condition occurs fairly often in the intestines

It is considered that the spread of extrauterine dystopic endometrium takes place by intracavitary wandering and secondary implantation (SAMPSON 1925) as well as by metastasis The condition may occur in cicatrices following hysterotomies as a result of implantation in the operation field, this has also been demonstrated experimentally (HARBITZ 1934) Such infiltrates arose after vaginal hysterotomy for termination of pregnancy in 20 % of a series of 810 women (LINDAHL 1958) According to another view (IWANOFF 1898) endometriosis may arise as a result of metaplasia of cell elements in the coelom epithelium The essentially benign nature of the complaint is however generally acknowledged

The external endometrium, like the intrauterine endometrium, is dependent on hormones External endometriosis consequently takes part in the various phases of the menstrual cycle, which means that there is a periodic hyperemia with edema formation, extravasation of blood, cellular infiltration, and repair This may lead to a fibroplastic reaction by the surrounding normal peritoneum and pelvic connective tissue, with fusion of the serous surfaces such as often occurs between the uterus and rectum Infiltration and obliteration of the recto uterine pouch, with roentgenographically demonstrable changes in the anterior wall of the rectosigmoid junction, were observed by THEANDER & WEHLIN (1961) in 6 out of 8 cases with pelvic endometriosis This results in forward angulation of the anterior rectal wall and a ridge shaped protrusion into the lumen, a so called shelf tumour (BLUMER 1909, cited by THEANDER & WEHLIN) The shrivelling of the tissue also produces abnormal folding of the mucosa, this change, however, is not pathognomonic of endometriosis but may also occur in association with cancerous infiltration and inflammatory states around the rectum (HULTBORN, MORALES & ROMANUS 1955, THEANDER & WEHLIN 1961, THEANDER, WEHLIN & LANGELAND 1963)

Intrauterine adenomyosis and external endometriosis seldom occur together Among 530 cases of uterine adenomyosis reported by SCOTT & TE-LINDE (1950), for instance, coexistent external endometriosis was observed in only 11 9 % of cases

The diagnosis of external endometriosis may be difficult, however, because it is sometimes combined with other changes, in SCOTT & TELINDE's series of 516 cases it was associated with myomatosis in 57 % and with chronic salpingitis in 21 %

Endometriosis is commonest in the 30—50 year age group in which, according to CULVER, PEREIRA & SEIBEL (1958), 75 % of the cases are found Among



Fig 1 Case 1 Thickening of the wall in the sigmoid colon with a relief of thin irregular folding without signs of infiltration in the mucous membrane



Fig 2 Case 2 Well-delimited expansion of the wall in lower part of sigmoid colon and narrowing of the lumen no sign of ulceration of the mucous membrane

At repeated roentgen examinations an uneven well-delimited mural thickening and a soft movable mucous membrane were evident in the lower part of the sigmoid colon (Fig 2) As there was no evidence of increased swelling before the menstrual periods a definite diagnosis of endometriosis was not considered justified although the appearances suggested this possibility

Operation (Sjövall) revealed a myoma the size of a golf ball which was enucleated At two sites in the sigmoid colon there were hard masses one upper pea sized adhering to the tube and a lower one nearly as large as a sixpenny piece with white streaky shrivelling of the serosa In view of the patient s a e intestinal resection was performed despite the possibility that the condition might have been endometriosis The specimen displayed an intact mucous membrane and the histologic diagnosis was endometriosis

Case 3 Woman aged 49 who had previously undergone an operation for myoma of the uterus uterine adenomyosis a follicular cyst of the right ovary and pelviperitoneal adhesions The uterus was amputated and the right ovary resected The colon was normal to palpation For the last six months the patient had had irregular bowel movements and periods of diarrhea had occasionally noticed blood and mucus in the stools had had aching pain in the lumbar region felt tired and was losing weight

At roentgen examinations on three occasions a walnut sized sharply delimited indentation into the lumen with transverse folds closely placed in a palisade like arrangement were evident in the lower part of the sigmoid colon (Fig 3) There were no signs of infiltration of the mucous membrane The appearances suggested endometriosis

Operation (Rudberg) revealed a few adhesions in the lower part of the abdomen as well as a hard walnut sized infiltration in the sigmoid colon and a subserous plum sized ovarian cy t

Endometriosis of the small intestine usually occurs in coils lying far down in the pelvis, and mainly in the distal ileum. Various types of stenosis may arise through the formation of expansive processes in the intestinal wall or by strangulation of the intestine (ECKER, DOANE & DICKSON 1964), when such conditions occur in the distal ileum they may simulate regional ileitis and peritoneal affections. In endometriosis, cyclic exacerbations may occur.

Endometriosis of the cecum seldom produces signs of stenosis unless Bauhin's valve is infiltrated. With this location it is usually a question of a polypoid tumour of benign appearance difficult to distinguish from a carcinoid or from carcinoma. Endometriosis of the appendix, is often located in the apical region, and attacks resembling those of appendicitis may occur, especially during menstruation.

The rectosigmoid region is by far the commonest location for intestinal endometriosis, about 70 % of cases occurring at this site.

A case of endometriosis of the sigmoid colon was diagnosed in 1936 by B. Lilja (JOSEFSSON 1939). Special roentgenologic characteristics, more marked during menstruation when the patient's symptoms were also more severe, were demonstrated for the first time. A short account will be given of this case, and of two other cases observed later by the present writers, as well of further two cases from other hospitals. (We wish to thank Prof. Saltzman, Umeå, and Dr Zachrisson, Skellefteå, for permission to publish these cases.)

Case reports

Case 1. Para III, aged 42, examined in 1936, no abortions. Over the last six months she had had increasingly severe constipation and colicky pain. At roentgen examinations over a period of three months a sharply delimited area of mural thickening roughly 8 cm long was evident, the mucous membrane with high irregular folding was apparently intact and without ulceration (Fig. 1). At the last examination, which was made during the menstrual *period* the intestinal lumen was seen to be narrower than at the previous examinations. As the appearances suggested neither malignancy nor inflammation, and as they were more marked *during* menstruation, endometriosis seemed a likely diagnosis. The clinical observations with more severe constipation and colicky pain during the menstrual periods appeared to corroborate this assumption.

An orange sized, well circumscribed tumour was removed at operation (Hogman). Histologic diagnosis: endometriosis. The after course was uneventful.

Case 2. Para 0, aged 33, no abortions. For about 2 years she had had transient pain in the lower left part of the abdomen, and during the last year the pain had set in half way between the menstrual periods and continued till the end of the period; it was becoming more intense and the patient had attacks of diarrhea. She was not troubled by *constipation*, and had not noticed bleeding from the intestines. Menstrual cycle: 4 days/4 weeks. No dysmenorrhea.

A gynecologic examination revealed a rounded mass slightly larger than a walnut and in broad contact with the uterus.



Fig 5 Case 5 A contrast medium defect of the same kind as in Case 4 is seen in the lower part of the sigmoid colon

Discussion

Endometriosis of the sigmoid colon is difficult to distinguish clinically from other conditions of the colon such as spastic colitis and carcinoma Rectal bleeding is common in the latter but seldom occurs in endometriosis although a few authors have reported a fairly high incidence (MAYO & MILLER 1940 11 out of 38 cases CULVER PEREIRA & SEIBEL 1958 4 out of 9 cases) When rectal bleeding occurs in association with endometriosis it is probably only occasionally the result of direct ulceration of the mucous membrane but would generally seem to be due to cyclic edema with exudation of bloody serous fluid

A roentgen diagnosis of endometriosis in the sigmoid could be made in two of the present cases (Cases 1 and 3) and in the third (Case 2) it was considered probable The examination made during menstruation in Case 1 disclosed marked aggravation of the swelling and increased constriction of the lumen In Case 3 the 49 year-old patient had ceased to menstruate after the uterus had been amputated for adenomyosis and in Case 2 the patient complained of accentuated intestinal pain before and during the menstrual periods

In Cases 4 and 5 the findings were very similar to those in Case 2 although they were not entirely unambiguous and the folding of the mucous membrane was absent In both cases compression of the intestinal wall from a tumour situated outside the intestine was considered the most likely explanation The regular surface and sharp delimitation are distinguishing features of this



Fig. 3. Case 3. A relief of thin irregular folding in a well demarcated area is seen in the sigmoid sling; the wall is thickened but the mucous membrane is intact.



Fig. 4. Case 4. A rounded well-demarcated contrast medium defect is seen in the sigmoid colon; no sign of ulceration of the mucous membran.

The sigmoid colon was resected: a hard tumour was present in the submucosa of the wall but the mucous membrane was intact. Histologic diagnosis: endometriosis of the sigmoid colon and a cystic corpus luteum of the ovary. The after course was uneventful.

Case 4. Woman, aged 41. (From Professor Saltzman, the Roentgendiagnostic Department, Umeå.) This patient had for many years had periodical attacks of pain in the lower part of the abdomen as well as defecation pain which for some years had been increasing in severity, especially before her menstrual periods. There were no palpable changes at the gynecologic examination. At roentgen examination a permanent well delimited broad based defect of circular shape and causing constriction of the lumen was evident in the contrast filling. No signs of ulceration of the mucous membrane (Fig. 4). The appearance was interpreted as an indentation into the sigmoid colon from an extra enteric process; the possibility of endometriosis was, however, also discussed.

At operation (Rais) a chestnut sized tumour was seen in the wall of the intestine under the intact mucous membrane. Resection was performed and the specimen contained a tumour slightly larger than a hazelnut in the intestinal wall under the mucous membrane. Histologic diagnosis: endometriosis.

Case 5. Woman, aged 40. (From Dr Zachrisson, the Roentgen Department, Skellefteå General Hospital.) Because of persistent increasingly severe attacks of diarrhea for about a year a roentgen examination was carried out and revealed a well delimited broad based defect the size of a walnut in the contrast filling at the point of transition between the sigmoid colon and the rectum (Fig. 5). Compression of the intestinal wall from without was considered to be the explanation.

At operation (Kjellgren) a fairly hard tumour mass was found in the sigmoid colon near the rectum. After resection the specimen proved to contain a tumour in the muscular coat of the intestinal wall covered by an intact mucous membrane. Histologic diagnosis: endometriosis.

difficult Case 2 is an example of this the nature of the findings however, in combination with the history of severe exacerbation of intestinal pain during the menstrual periods led to a correct diagnosis despite the absence of the typically folded mucous membrane In Cases 4 and 5 with similar appearances the changes were considered to be probably due to indentation by extra enteric tumours These two cases illustrate the diagnostic difficulties that may be encountered A good knowledge of the appearances produced by endometriosis will however aid in reducing them

A contrast study should be made during menstruation and if the changes then appear more marked this provides further support in favour of the diagnosis RIEDERER (1962), who noted premenstrual swelling of the mucous membrane in two cases has stressed the importance of such a finding

Atypical or ambiguous appearances are however also seen in endometriosis, especially when the endometriotic tumour does not have the usual polypoid form but tends to develop around the intestine and cause a concentric stenosis of greater or lesser severity Such appearances have been reported by MACAFEE & GREER (1960)

Folding of the mucous membrane with serrations may occur in association with sigmoiditis and perisigmoiditis conditions that may also be present in a more or less circumscribed form in the latter however, the folds are usually irregular and edematous, and the appearances are of a quite different character Sigmoiditis is furthermore commonest in the elderly, and not infrequently is combined with diverticulosis whereas rectosigmoidal endometriosis is rare in women past the menopause Ten postmenopausal cases (7 %) were reported by MACAFEE & GREER (1960) in a material of 142 cases of intestinal endometriosis assembled from several publications and COLCOCK & LAMPHIER in 1950 had observed 2 cases over 65 years of age KEMPERS DOCKERTY HUNT & SYMMONDS (1960) have observed 24 cases of postmenopausal endometriosis 8 situated in the intestines

Although endometriosis cannot always be diagnosed roentgenographically the appearances are often so typical that the diagnosis may be made with a high degree of certainty

It is worth mentioning that malignant metaplasia — or at least coincident malignant degeneration — has been observed in the dystopic endometrium in a few cases (JENKINSON & BROWN 1943 FREDRIKSSON 1953 MACAFEE & GREER 1960 FRIEBEL 1963)

The fact that endometriosis usually declines with the hormonal changes associated with the menopause should be borne in mind when therapy is being planned The patient s symptoms age and other such factors should be carefully weighed before the choice is made between surgery hormone therapy

change, as compared with the appearances produced by carcinomatous infiltration, and they also differ from those usually seen in polyps

Although several cases with similar roentgenographic appearances have been reported (JENKINSON & BROWN 1943, McGUFF, DOCKERTY, WAUGH & RANDALL 1948, BOLFS & HODES 1958, CRISMER & GUILLARD 1962, DAVIS, ALEXANDER & BUENGER 1963) opinions regarding the possibility of establishing a diagnosis still differ HENRIKSEN (1955) stated that 'roentgen studies have revealed no characteristic pattern that would assist in the diagnosis WIETERSEN & BALOW (1957) described 9 cases of intestinal endometriosis, in 8 cases it was located in the sigmoid The roentgenograms revealed an intact but distorted and displaced mucous membrane These authors wrote 'We believe that with more frequent roentgen study of the colon the incidence of endometriosis will be found to be higher than has been suspected' CULVER, PEREIRA & SEIBEL (1958) published 7 cases of endometriosis in the rectosigmoid region, a roentgen diagnosis of endometriosis had been made in four of them, while in the other three the roentgen diagnosis was a submucous tumor, an extrinsic tumor in a patient of postmenopausal age, and pericolitis in a 47 year old patient with diverticula These investigators considered that in typical cases 'the findings are sufficiently characteristic that, when combined with the clinical data, a correct diagnosis should be possible in most cases SPJUT & PERKINS (1959) made a report on 6 cases, and although only one of these had been diagnosed preoperatively on the basis of the roentgen findings they added In general the problem of an accurate clinical diagnosis of endometriosis rests first and foremost with the radiologist MACAFEE & GREER (1960) considered that the difficulty of differentiating between involvement of the bowel by endometriosis or by carcinoma is rightly stressed by all writers , and THEANDER & WEHLIN (1961) remarked that it is still widely believed that the roentgen appearances of the condition are uncharacteristic and of little help in establishing the diagnosis in clinically doubtful cases

The present cases, as well as those in other publications, demonstrate that intestinal endometriosis produces the appearances of a polypoid tumor bulging into the lumen and with a mucous membrane that appears creased into rather high narrow folds crowded together in a palisade like arrangement It is difficult to decide whether this folding is caused by a local disturbance in the motor apparatus of the intestinal wall or by partial shrivelling and contraction of the wall The borders to the surrounding structures are regular The most prominent feature is that the mucous membrane is soft and flexible, and thus is intact The findings differ noticeably from the stiff, ulcerated, ragged appearances produced by carcinomatous infiltration

If the endometriotic growth is small its differentiation from a polyp is more

lifficult Case 2 is an example of this, the nature of the findings, however, n combination with the history of severe exacerbation of intestinal pain during he menstrual periods led to a correct diagnosis despite the absence of the typi cally folded mucous membrane In Cases 4 and 5 with similar appearances the changes were considered to be probably due to indentation by extra enteric tumours These two cases illustrate the diagnostic difficulties that may be encountered A good knowledge of the appearances produced by endometriosis will however aid in reducing them

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The fact that endometriosis usually declines with the hormonal changes associated with the menopause should be borne in mind when therapy is being planned The patient s symptoms age and other such factors should be carefully weighed before the choice is made between surgery, hormone therapy,

or castration. In 102 cases assembled from the literature by MACAFEE & GREER (1960) two thirds had been treated by intestinal resection, while SCOTT & TE LINDE (1950) did not perform resection in any of their 19 cases. A correct pre- or intraoperative diagnosis is also of significance in the choice of operative method, since a complaint so benign as endometriosis does not seem to warrant such radical surgical measures as are used for malignant tumours which involve the application of a permanent colostomy or excision of the rectum.

SUMMARY

A short account of the occurrence of endometriosis is followed by a description of five cases in which the condition was situated in the sigmoid colon. In three of the cases the roentgen findings led to a correct diagnosis, whereas in the two other cases the cause of the changes in the colon could not be roentgenographically stated. A preoperative diagnosis is of importance for the planning of the treatment, especially in cases likely to respond to hormone therapy.

ZUSAMMENFASSUNG

Das Vorkommen der Endometriose wird erörtert. Von fünf Fällen, in denen das Sigma befallen war, konnte die Endometriose in drei Fällen röntgenologisch diagnostiziert werden, in den beiden anderen konnte die Genese der Veränderungen durch die Röntgenuntersuchung nicht festgestellt werden. Die Möglichkeit, diese Erkrankung vor der Operation zu erkennen, hilft bei der Planung der Behandlung, die bisweilen durch Hormontherapie allein unternommen werden kann.

RÉSUMÉ

Les auteurs rappellent les conditions d'apparition de l'endométriose et décrivent cinq cas de localisation sigmoïdienne de cette affection. Dans trois de ces cas, les signes radiologiques ont conduit au diagnostic correct, alors que dans les deux autres la radiologie n'a pas permis d'établir la cause des lésions coliques. Il est important de faire un diagnostic pré-opératoire, certains cas pouvant être sensibles à l'hormonothérapie.

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FROM THE DEPARTMENT OF DIAGNOSTIC ROENTGENOLOGY (ACTING DIRECTOR ASST PROF N EDLING), KAROLINSKA SJUKHUSET, STOCKHOLM, SWEDEN

RADIOLOGIC PELVIMETRY WITH SPECIAL REFERENCE TO WIDEST TRANSVERSE DIAMETER OF PELVIC INLET

by

J DIEHL and I FERNSTROM

Pelvimetry may be performed satisfactorily by mensuration of (1) the sagittal diameter of the pelvic inlet (2) the sagittal diameter of the pelvic outlet and (3) the interspinous and (4) the intertuberous diameters of the pelvis If the sagittal diameter of the pelvic inlet lies between 10 cm and 11 cm its widest transverse diameter (WTDI) should also be determined this is rarely required in practice however as the former generally exceeds 11 cm (BORELL & FERNSTROM 1960)

Numerous methods of determining the WTDI have been described the orthographic technique published by JOHANSSON (1956) being the most reliable The over couch tube is used and the beam diaphragm is adjusted so that the rays are allowed to penetrate only through a slit During the exposure the tube is moved from right to left of the patient and parallel to the film As there is no distortion due to magnification it is not necessary to correct

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the measurements obtained directly from the film This technique requires however special roentgen equipment, and it is therefore comparatively rarely used

The stereometric method described by Nicholson (1956), which is referred to as 'method I' throughout this paper, comes next in accuracy This technique makes use of a single film in which two exposures are made, the measurements of the WTDI being obtained by simple mathematical computation

The majority of the other available methods are more or less based on the following principles An a p view of the pelvic inlet is obtained, on which the WTDI is measured Owing to the divergence of the rays the measurement value will be greater than the true one and require correction The simplest but least reliable method of determining the magnification factor is to locate the upper border of the symphysis pubis and to measure its distance from the film The magnification factor can be assessed with greater accuracy by obtaining a lateral view in addition to the a p view The distance between the WTDI and the plane of the a p film can be estimated in the lateral view directly from a centimetre scale, and the magnification factor for the WTDI is then easily calculated This method (method II in the present paper), which has been described by several workers, has the disadvantage that the plane in which the WTDI lies is difficult to locate accurately in the lateral view (for details of the technique, see Borell & Fernstrom 1960)

The accuracy of method II was investigated by comparing the results with those obtained by method I, both methods were tested in patients and with dried pelves on which the WTDI could be directly measured

Some workers have abandoned radiologic pelvimetry in view of the inevitable hazards of ionising radiations Others, appreciating its value in obstetric prognosis, have continued to use it but have narrowed the indications and have reduced the radiation dose to the maternal ovaries and foetal gonads by restricting the number of roentgenograms and abandoning the projections that involve large radiation doses The present authors were therefore prompted to investigate whether the determination of the WTDI was feasible in the projection used by Borell & Radberg (1964) for the mensuration of these two transverse diameters of the distal part of the pelvis The orthodiagraphic pelvimetry used by these workers permits the mensuration of those diameters with fair accuracy, and we have recently modified the method so as to enable the film to be used for the determination also of the WTDI The radiation dose to the maternal ovaries and foetal gonads is thereby substantially reduced for the cases in which the mensuration of the WTDI is also required This method, which we call method III, and its reliability will now be discussed in greater detail

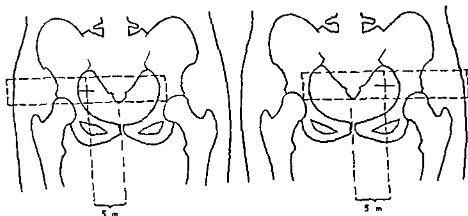


Fig 1 Schematic representation of the size of the fields (shaded areas) used for the two exposures in method I

Case material The three methods were tested in 58 patients referred to us because disproportion was clinically considered probable All three methods were used in 42 patients only methods I and III in 4 and only methods II and III in 12 patients Methods I and III were also employed in measuring 12 dried pelves of various sizes and shapes

Definition of the widest transverse diameter of the pelvic inlet The WTDI is commonly defined as the maximum distance between any two symmetrically placed points on the linea terminalis However the latter is in fact no true line but an oblique ridge on the inner surface of the ilium separating the true from the false pelvis It is therefore inexpedient to use the linea terminalis for the determination of the end points of the WTDI as their choice is inevitably influenced by subjective opinion Since the end points of this diameter hould be clearly defined the distance between the widest symmetrical points on the pelvic inlet in an orthographic projection of the pelvis may be regarded as the WTDI

Technical procedures

Method I With the patient supine the casette without a secondary grid is placed between the buttocks and the roentgen couch The over couch tube is used with the beam vertical the light beam diaphragm being adjusted so that an area 5 cm by 26 cm is projected onto the film The tube is centred over a point 5 cm above the upper border of the symphysis and 5 cm to the left of the patient s midline and the first exposure is made Without changing the positions of patient and cassette the tube is re centred 5 cm to the right of the

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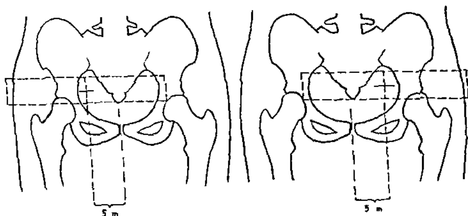


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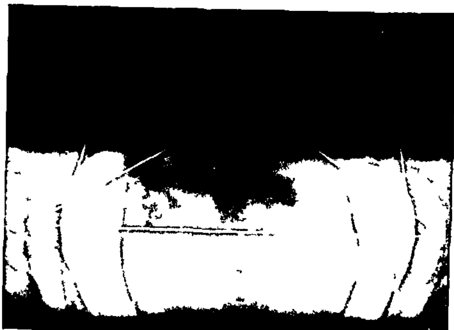


Fig 2 Roentgenogram obtained by method I

midline, and the second exposure is made The size of fields is shown in Fig 1 and the roentgenogram obtained in Fig 2

The technique is based on the assumption that the WTDI, the axis along which the tube is shifted, and the film all lie parallel to each other The following construction (see Fig 3) was used to simplify the mathematical computation of the true measurement of the WTDI A transverse line was drawn on the film joining the most widely spaced symmetrical points (B and C in Fig 3) on the two medial contours of the pelvic inlet This line was extended so that it also crossed the two lateral contours (at A and D, Fig 3) of the pelvic inlet, parallel to this, another line was drawn, on which a length of 10 cm was marked off (Fig 3, line E and F) This length corresponded to that over which the tube was shifted By simple mathematical computation it was found that the distance between the parallel lines AD and EF is of no mathematical importance Lines were then drawn from E to B and D, and from F to A and C These lines reflect the path of the rays at the two exposures It can be proved by mathematical computation that the WTDI, (T_1), is the distance between the points of intersection of these lines (G and H in Fig 3)

Alternatively, the following formula may be used in the calculation of the

WTDI $T_1 = \frac{10\,(a+b)}{10+a}$ (Fig 3)

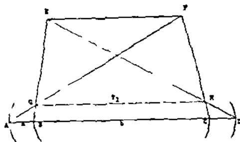


Fig 3 Diagram for estimation of WTDI by method I B and C = symmetrical points on the two medial contours of pelvic inlet b = line joining these points A and D = points of intersection of extended line b and the two lateral contours of the pelvic inlet FF = a line 10 cm long and parallel to b G = point of intersection of lines FA and EB H = point of intersection of lines ED and FC and T_1 = widest transverse diameter of the pelvic inlet (WTDI)

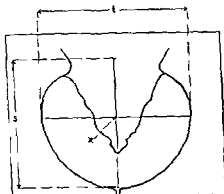


Fig 4 Diagram illustrating the calculation of the WTDI in the films obtained by method II The point of intersection (x) of the WTDI (t) and the sagittal diameter (s) is ascertained in the a p view and the corresponding point in the lateral view The distance between the plane of the WTDI and the plane of the film is estimated by reference to the centimetre scale

Method II The patient lies supine and a metal rod with a centimetre scale is placed vertically at the patient's vulva An a p view of the inlet is taken, using the over couch tube with the beam vertical and the FFD is measured Without changing the patient's position a lateral view to include the promontory the symphysis pubis and the centimetre scale, is obtained The point of intersection of the sagittal diameter and the WTDI is ascertained in the a p view (in Fig 4) and the corresponding point is then calculated in the lateral view The distance between this point of intersection in Fig 4 and the plane of the film is estimated by reference to the centimetre scale The WTDI is then calculated using the formula

$$T = \frac{t\,(F-h)}{F}$$

where T_2 is the corrected value of WTDI t the apparent WTDI, as measured directly on the film F the FFD and h the distance between the point of intersection of sagittal diameter and WTDI and the plane of the film



Fig 5 Roentgenogram obtained by method III showing the end points of the W TDI

Method III This method, as already mentioned, is a modification of th described by BORELL & RADBERG (1964) It permits the projection of the outlin of the ischial spines into the obturator foramina and the demonstration of th ischial tuberosities

The patient in the original method lies supine with the knees flexed, th thighs abducted about 15° and the buttocks resting on the cassette The over couch tube is used at a FTD of 125 cm without a secondary grid The ligh diaphragm is adjusted so that an area of 5 to 6 cm by 10 to 11 cm is projecte onto the film The tube is angled 20° cranially and centred over a point 4 to 5 cm below the upper border of the symphysis pubis Two exposures are mad without changing the patient s position, the tube being shifted 5 cm to the right of the midline for the first exposure and 5 cm to the left for the second exposure

The following modifications of this method have been made by the present writers (1) the light diaphragm is adjusted so that an area 6 cm by 13 cm, is projected onto the film, (2) the tube is centred over a point 2 cm below the upper border of the symphysis, (3) the tube is angled 22 5 cranially, exposure factors 150 mA 54 kV and 4 0 seconds The roentgenogram obtained is shown in Fig 5

This technique enables the lateral walls of the pelvic inlet, between the upper border of the pubis and the lower medial border of the ilium, to be demonstrat



Fig 6 Roentgenogram obtained by method III The end points of the WTDI are difficult to identify (cf fig 5) and are located by following the two medial walls of the true pelvis to the points where they intersect the upper border of the pubic bone or its linear projection

ed It was observed that overlapping of these bones due to inclination of the pelvic inlet may occasionally occur (Fig 6) and prevent the arcuate line being followed along the upper border of the pubis as far as the ilium In these cases it was therefore not possible to use this line for the demonstration of the end points of the WTDI This observation prompted us to regard the point of intersection of the upper border of the pubic bone or its linear projection and the medial cortical surface of the ilium (generally called the medial wall of the true pelvis) as the end points of the WTDI (Fig 6)

In contrast to methods I and II magnification of the WTDI due to divergence of the rays was not taken into account when calculating this diameter by method III The magnification factor cannot be arrived at unless the distance between the WTDI and the plane of the film is known This distance in method II was measured in the lateral view the mean measurement being 11 0 cm in the 54 patients examined by this method As the position of the patient s legs in method II differs slightly from that in method III the angle of the inclination of the pelvis also differs somewhat and results in the distance between the WTDI and the plane of the film being occasionally slightly greater than in method III The measurement of the WTDI to film plane

was used to correct the measurement of the WTDI, as obtained by method III and using the following formula

$$kT_s = \frac{T_s (F - 11.0) + 11.0}{F}$$

where kT_s is the corrected measurement of WTDI, T_s is the WTDI, as measured directly on the film, and F the FFD

In order to check whether the measurements of the WTDI, as obtained by methods I and III, corresponded to the true ones, this diameter was determined by pelvimetry on 12 dried pelves and compared with direct measurements Care was taken to see that the WTDI lay 11 cm above the film and that the position of the model corresponded to that of the pelvis of a patient lying supine in placing these models on the roentgen couch

Results

The range and average measurements of the WTDI obtained in the 12 patients examined by all three methods are given below

Method	*Minimum*	*Maximum*	*Average*
I	11.1 cm	14.8 cm	13.18 cm
II	11.3 cm	14.4 cm	13.15 cm
III	12.1 cm	15.8 cm	14.00 cm
Corrected measurements (method III)	11.7 cm	15.1 cm	13.53 cm

Comparative studies indicated that the measurement values obtained by method I were generally greater than those obtained by method II, the average difference being 0.33 cm and in no instance greater than 0.7 cm

Comparison of the measurements given by methods I and III disclosed that the latter were from 0.2 cm to 1.0 cm greater than the former, the average difference being 0.52 cm After correction, the measurements obtained by method III differed from the corresponding measurements obtained by method I by from + 0.4 cm to − 0.2 cm, the average difference being 0.05 cm greater in method III

Analysis of the measurements made on the 12 dried pelves by means of calipers indicated that the average WTDI was 13.02 cm The measurements obtained by method I on 5 of these models were 0.1 cm smaller and on the other 7 models were identical with those established by calipers the average being [illegible] The measurements established by method III were corrected

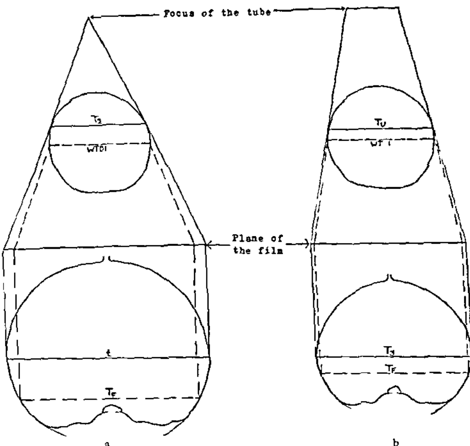


Fig 7 Schematic representation of the sources of error due to the divergence of rays inherent in the three methods The distance between the focus and the WTDI is shortened in order to illustrate them more clearly WTDI = widest transverse diameter of the pelvic inlet and TF = WTDI as projected onto the film a) *Method II* t = WTDI as measured directly in the film T = calculated WTDI b) *Methods I and III* T = WTDI as measured in the film T_u = calculated WTDI

as described above the corrected measurements being 0 1 cm smaller for 4 models and 0 1 cm larger for 2 models than those obtained by calipers for the other 6 models the two measurements were identical the average corrected measurement being 13 00 cm

Discussion

It may be seen from the tabular data that the results of the three methods varied All methods had sources of error most of these being due to the tech

nique used in taking the films One source of error common to all three methods arose from the fact that the WTDI was measured between two points at which divergent rays strike the pelvic brim (Fig 7) This error was greatest with method II and less in methods I and III in which the divergence of the rays was smaller The errors in methods I and III were of the same order of magnitude This error is eliminated in the latter method if the actual measurement of the WTDI is identical with the length of the axis over which the tube is shifted In practice this error is negligible, however, being at most 0 05 cm if the true WTDI is 13 cm

Analysis of other possible sources of error in the three methods revealed the following points

Method I The measurements of the WTDI made on the twelve dried pelves indicated that those obtained by method I did not deviate by more than 0 1 cm from the true figures This source of error probably arose from errors in mensuration on the films

Method II It is difficult to determine accurately the plane of the WTDI on the lateral view obtained by this method, which probably accounts for the difference between the measurements with methods I and II, shown in the table on p 564 The measurements obtained by method I were sometimes as much as 0 7 cm greater than those established by method II

Method III The average measurement of the distance between the plane of the film and the WTDI as calculated from the lateral view obtained by method II, was used for the calculation of the magnification factor of the WTDI The average measurement of this distance differed slightly from the true one, as already mentioned Nevertheless, the average seems to be useful in practice because the corrected measurements of the WTDI by method III deviated considerably less from the measurements obtained by method I, which virtually corresponded to the true ones The difference between methods I and III, as regards the corrected measurements of the WTDI, varied between — 0 2 cm and + 0 4 cm the average being + 0 05 cm This difference was partly due to the fact that the distance between the plane of the film and the WTDI was assumed to be constant (11 cm) in the individual cases while it actually varied between 9 1 cm and 13 7 cm The calculated measurements as compared with the true ones were however never greater than 0 20 cm

It is evident from what has been said that method II gives less accurate measurements than method I, the difference sometimes amounting to 0 7 cm,

it was not possible to correct this error Method I seems to be superior because (1) it is easy to perform and (2) its sources of error are negligible

If methods I or II are used in pelvimetry more exposures are required and the maternal ovaries and foetal gonads will receive a larger radiation dose than with method III If the magnification factor of the WTDI is corrected, method III gives measurements that are more accurate than those established by method II, though less accurate than the measurements produced by method I the difference between the measurements being occasionally 0 4 cm but generally much smaller

The WTDI in Swedish women is usually about 13 cm and rarely less than 12 cm According to McLane (1962) disproportion is likely if the WTDI is 11 cm or under Borell & Fernstrom (1960) observed however that labour may proceed normally if the WTDI is 11 cm and the sagittal diameter of the pelvic inlet is wide The present authors feel that there is risk of disproportion only if both the WTDI and the sagittal diameter of the inlet are reduced Determination of the WTDI is therefore required when the sagittal diameter is between 10 cm and 11 cm The measurements obtained with method III never deviated by more than 0 4 cm from the true ones as already mentioned This difference is negligible in assessing the capacity of the pelvic inlet

Method III would appear to be superior to method I and II becuase it also enable the transverse diameters of the distal part of the pelvis to be determined We therefore recommend that it be as an adjunct to routine pelvimetry and that the following procedure is applied

Commence by taking a lateral view of the pelvis with the patient erect measure the sagittal diameter of the pelvic inlet and if this lies between 10 cm and 11 cm take an a p view using method III If the sagittal diameter exceeds 11 cm the WTDI is of no prognostic importance In such cases obtain an a p view by the method described by Borell & Radberg (1964) With the sagittal diameter less than 10 cm the danger of disproportion arises then no further roentgen films should be taken but the possibility of Caesarean section sould be considered

The measurement of the WTDI as obtained directly from the roentgenogram by method III should be corrected For practical purposes the following formula is recommended instead of the earlier given

$$\text{WTDI} = k\ (T_s - 10) + 10$$

where k is a constant that can be calculated for any apparatus if the FFD (F) is known and equals $\frac{F-11}{F}$ and T_s equals the uncorrected measurements obtained with method III

SUMMARY

A new method of determining the widest transverse diameter of the pelvic inlet a modification of the method described by BORELL & RÅDBERG (1964) for mensuration of the pelvis is presented It has many advantages the chief of which being that the radiation doses to the maternal ovaries and foetal gonads are greatly reduced

ZUSAMMENFASSUNG

Eine neue Methode zur Bestimmung des weitesten Transversaldurchmessers der Eingangsebene des Beckens wird angegeben Diese Methode ist eine Modifikation der von BORELL und RÅDBERG (1964) angegebenen Methode der Beckenmessung Der Vorzug ist hauptsächlich in der Herabsetzung der Strahlendose in den Ovarien der Mutter und den Sexualorganen des Kindes zu ersehen

RÉSUMÉ

Présentation d une nouvelle méthode de mesure du plus grand diamètre transversal du détroit supérieur modification de la méthode de pelvimétrie décrite par BORELL et RADBERG (1964) Elle présente de nombreux avantages dont le principal est l importante réduction de l irradiation des ovaires de la mère et des gonades du foetus

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FROM THE RADIOLOGIC CLINIC (DIRECTOR PROF J HOLY) OF THE FACULTY OF MEDICINE J E PURKYNE S UNIVERSITY OF BRNO CZECHOSLOVAKIA

VERTEBRO MEDULLARY INTERRELATIONS AS OBSERVED IN GAS MYELOGRAPHY

by

M ROTH

The ventral subarachnoid space in the thoracic part of the spinal canal at gas myelography under normal conditions appears consistently filled The whole ventral subarachnoid space is of fairly uniform depth except for a gradual narrowing at the level of the lumbar intumescence which curves slightly ventrad The dorsal subarachnoid space is usually less distinctly outlined with gas since the cord mainly runs in proximity to the dorsal wall of the membranous sac especially in the lower half of the thoracic region (Fig 1) It has been suggested (ROTH 1963) that this anatomical arrangement is due essentially to developmental factors

The ventral curvature of the caudal end of the spinal cord partly arises from the exaggerated curvature of the hind end of the embryo (STERZI 1914) and partly from the ventrodistally directed course of the lumbar spinal nerves The thoracic spinal nerves on the other hand run a dorsally directed course and contribute to the dorsal position of the cord in the thoracic part of the membranous sac VON LANZ (1929) constructed the geometrical resultant of the traction effect of the nerve roots he applied it however, only to the dural

Submitted for publication 12 October 1964

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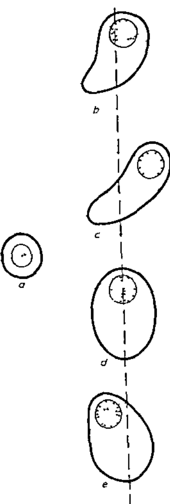


Fig 2



Fig 3a



Fig 3b

Fig 2 Different shapes of the intervertebral foramina a) Fetal the spinal nerve runs centrally through its foramen with the ascent of the cord a plastic modelling of the foramina typical of the respective areas takes place b) Cranial thoracic c) caudal thoracic d) thoraco-lumbar and e) lumbar

Fig 3 a) Shaping of the intervertebral foramina in a boy aged 9 b) Intervertebral foramina in an adult in the region of the thoraco lumbar junction

point lying ventrad at the level of the ventral wall of the spinal canal In the proximal thoracic portion and in the area of the thoracolumbar junction the foramina assume an intermediate shape with the most proximal point situated approximately midway between the ventral and dorsal wall of the spinal canal During the ascent of the cord each spinal nerve — in the early embroyonal period running centrally through its intervertebral foramen — assumes a cranially directed eccentric position in the foramen (TONDURY 1958) with a concomittant dorsal shift in the thoracic foramen and ventral shift in the lumbar foramen

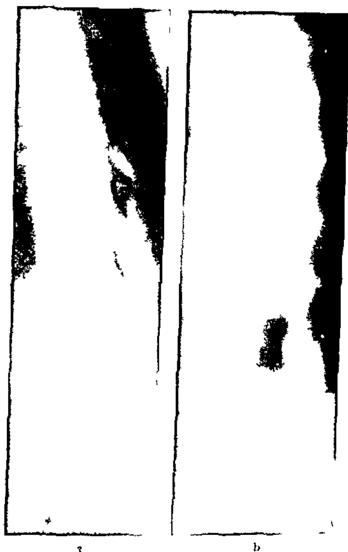


Fig 1 Normal tomo pneumo myelogram in an adult (a) and a child (b) The spinal cord runs along the dorsal wall of the membranous sac except for the lumbar intumescence which is curved ventrad and comes in close contact with the ventral wall of the sac

sac It would appear that the spinal cord is also influenced by this effect, especially in the thoracic region where the spinal nerves are not firmly anchored in the intervertebral foramina as with the cervical and lumbosacral nerves (VON LANZ) so that traction of the former can be freely transferred to the cord

The varying courses of the spinal nerves are reflected in the different *anatomical arrangements of the intervertebral foramina* (Figs 2 and 3) These latter are pear shaped in the thoracic region, the long axis being dorso cranially directed so that the most proximal point (i e the exit of the spinal nerve) is situated roughly at the level of the dorsal wall of the spinal canal The lumbar foramina are on the contrary kidney shaped, with their proximal



Fig 3 Atresia of the ventral subarachnoid space a) Spinal cord attached to ventral wall of spinal canal from D6—D7 downwards Above this level the cord normally runs along the dorsal wall b) Another patient The caudal end of the cord is intimately attached to the ventral wall of the spinal canal

o the respective pedicles as compared with the other ribs (Fig 4) Taking he arrangement of the ribs as at least a rough indicator of the course of the xtradural portions of the spinal nerves the Pfitzner phenomenon stands out learly in the a p film of the thoracic spine WITZLEB (1933) has shown hat the dorsally directed divergence of the so-called ribaxes (i e the lines onnecting the midpoints of the costo vertebral and costo transversal joints) liminishes in the craniocaudal direction Whereas the dorsal angulation of he first pair of ribaxes amounts to a mean value of 127 5 with the tenth pair t is only 56 3 thus proving a steeper course dorsally of the caudal ribs

The Pfitzner phenomenon reflects obviously a complex and hitherto poorly understood developmental process leading to the establishment of the para vertebral gutter of the dorsal thoracic wall quite characteristic for man or, more precisely for the erect posture (POPOVA LATKINA 1964) The spinal nerves must inevitably be involved in this process Their complicated traction effect brought about by the ascent of the spinal cord and by the formation of the paravertebral gutter besides implying the typical dorsal position of the cord in the membranous sac results in plastic modelling of the intervertebral foramina The term modelling is in keeping with HOLTZER s (1952) experimental observations about the influence of nerve bundles upon the arrangement of pre-cartilage cells

The significance of the dentate ligaments in fixation of the spinal cord in

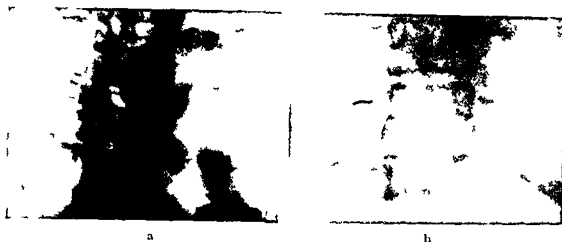


Fig. 4. Different positions of the cranial (a) and caudal (b) ribs in relation to the pedicles.

More abundant gas filling of the dorsal *subarachnoid space is sometimes* encountered under normal conditions in the upper half of the thoracic portion where the cord may become detached from the dorsal wall of the membranous sac. Our tomographic device offers no possibility of obtaining lateral views with the patient prone or supine. JIROUT (1963), with conventional films, in a fairly high percentage of cases, has demonstrated changes in position *of the thoracic spinal cord with the posture of the body. In the prone posture* the cord moves forwards and the ventral subarachnoid space gets narrower. This mobility of the cord in his series was distinctly greater in the upper than in the lower thoracic region. Nevertheless, according to BONTE, DELROSSE & CECILLE (1960), even with the patient prone the cord remains not infrequently attached to the dorsal wall of the membranous sac despite the influence of gravity. It appears to the writer that the somewhat different *anatomical shapes of the upper and lower thoracic intervertebral foramina*, implying a slightly more ventrad situated point of exit of the upper thoracic spinal nerves in comparison with the lower ones (Figs 2b, 2c and 3a) offer the most plausible explanation of this otherwise hardly comprehensible difference in response of the cord to gravity.

The more intimate dorsal adherence of the cord in the *lower thoracic portion is additionally favoured by the phenomenon described* by PFITZNER, as early as 1884, and consisting in increased angulation, even under 90°, between the intra- and extradural portion of the D7—D10 nerves, which ensues obviously from increased tension upon the nerves in active periods of growth of the axial skeleton and of the thoracic cage. In this connection it is interesting to note the more cranial position *of the 7th to 10th pairs of ribs in relation*





Fig 8 Variations in obliquity of the thoracic intervertebral foramina Those in children (left) are less steeply oriented than in adults (right) (See also fig 3)

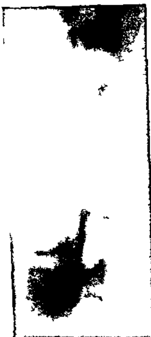


Fig 9 Vertical type of foramina in an over-developed boy aged 12 narrow ventral subarachnoid space

space especially in the lower thoracic region since it is normally the upper thoracic cord that displays the greatest antero posterior mobility

Embryology offers the most likely explanation According to HOCHSTETTER (1934) (Fig 6) the dorsal subarachnoid space appears at an earlier embryonal period than the ventral one which is formed distinctly later by vacuolisation of the ventral layer of the primitive leptomeninx Before the vacuolisation takes place the originally thick ventral layer of the primitive leptomeninx becomes thinner so that the spinal cord at this stage of development comes to lie ventrad in close proximity to the dorsal aspect of the vertebral bodies until later a communication of the ventral with the dorsal subarachnoid space between the ventral nerve roots and the dentate ligaments is established In the light of these developmental processes atresia of the ventral subarachnoid space (analogous to similar anomalies well known e g from the alimentary tract) appears a very likely explanation

The ventral position of the thoracic spinal ganglia at this stage of development is also shown in Fig 6 At later stages induced apparently by forming



Fig. 6

Fig 6 The dorsal part of the spinal subarachnoid space appears earlier than the ventral one so that the spinal cord at this stage of development (fetus 31 5 mm) comes to lie ventrad in close proximity to the vertebral bodies (From HOCHSTETTER 1934 Courtesy of Akad Verlagsges Geest und Portig K C Leipzig)



Fig 7

Fig 7 Spinal cord separated from the wide dorsal extradural space by the slit like dorsal subarachnoid space

the sagittal direction appears in this connection to be of only secondary importance (REID 1960)

In isolated instances — three times during 212 gas myelographic examinations — a complete absence of filling of the ventral subarachnoid space was encountered, with the cord resting directly on the ventral wall of the spinal canal and the dorsal subarachnoid space exceptionally well air filled, i e an actual reversal of the normal conditions In two instances this ventral position of the cord was total throughout the thoracic portion (the cervical unfortunately not having been investigated) The first impression gained was that the cord simply gravitated to the ventral wall of the sac *Nevertheless*, in the third instance (Fig 5a) only the caudal part of the cord exhibited the atypical ventral position, the cranial part running as usual along the dorsal wall of the membranous sac A rather sharply curved S shaped transitional segment of the cord is evident at the level of D6—7 and is obviously difficult to explain by mere gravity Moreover in simple ventrad gravitating of the cord there usually remains at least a strip of gas in the ventral subarachnoid



Fig 10 V t cal location nd small si of the intervert b al fo am na the ventral suba rachn d spac is sh llow

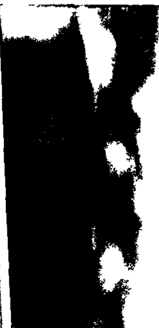


Fig 11 Hernia D11 D12 and protrus on D12 L1 both encroaching upon sp nal co d owing to the nar row vent al subarachno d space



Fig 12 Scheuermann s hyper kyphosis shallow ver tral subarachnoid space small disk hernia at D10 11 encroach ng upon the sp nal cord

The thoracic ventral extradural space is only a potential one in that the dural sac is in direct contact with the posterior longitudinal ligament, only sparse areolar tissue connects the two structures (CLARA 1959) The dorsal extradural space is significantly wider than the ventral space in the thoracic region neurosurgeons appraising its depth to several millimeters The exact assessment of this space in gas myelograms is usually difficult because of a rich fat content rendering the roentgenographic contrast rather poor It is therefore easy to gain the false impression that the thoracic part of the dorsal subarachnoid space is fairly wide and extends as far as the dorsal wall of the bony spinal canal (Fig 7) In hyperkyphosis especially the dorsal extradural space is widened (LINDGREN 1941) and prone to evoke the described misinterpretation

The depth of the ventral subarachnoid space is further significantly influenced by the sagittal diameter of the bony spinal canal Hitherto attention was focused almost exclusively to the cervical region where the assessment of the sagittal

of the paravertebral gutter, a dorsal migration of these structures together with the spinal cord must take place

The presumption of some 'traction' of the spinal nerves is in adults of course open to criticism, since the nerve roots do not take a straight but a slightly arching course in the membranous sac (CLARA 1959) BREIG (1960) has shown that dorsal extension of the cervical spine leads to slackening of the spinal cord and the *nerve roots down the whole length of the spinal canal*, with resulting increased mobility of the cord, whereas in ventroflexion of the cervical spine stretching of these structures takes place In a state of slackening, of course, the nerve roots cannot impart to the cord any fixed position in the spinal canal Nevertheless, it should be remembered that most of the life situations of man are associated with more or less marked ventroflexion of the cervical spine, extension being rather exceptional, so that in man the spinal nerve roots tend to persist in a state of slight tension Inspiratory movements of the ribs contribute also in all probability to the tension of the thoracic spinal nerves *BREIG & MARIONS (1963), with inspiration, observed increased movement* of the cervical spinal cord and nerve roots

The sagittal depth of the ventral subarachnoid space, as seen in the gas myelogram, varies within a fairly wide range, values up to between 5 and 6 mm may be reasonably looked upon as normal The 8 to 9 mm wide ventral subarachnoid space in severe atrophy of the cord is obviously abnormal The assessment of borderline values is of course extremely difficult although of utmost importance in myelographic interpretation The depth of the ventral subarachnoid space depends upon several anatomical factors, viz the thickness of the spinal cord, *the depth of the dorsal subarachnoid and the dorsal ex*tradural space, as well as upon the sagittal diameter of the bony spinal canal

The assessment of the sagittal diameter of the spinal cord is possible only in those cases where the dorsal subarachnoid space is gas filled This was evident in about 30 per cent of the present material in which values conforming on the whole to those reported by KLEFENBERG & SALTZMAN (1959) and by ELLIOTT (1945), i e values between 6 to 8 mm were recorded Of course, no absolutely symptom free subjects undergo gas myelography *so that the* possibility that some degree of diffuse thinning of the cord due to atrophy *may be responsible for the low values can never with certainty be excluded* Sufficient evidence exists that a fair degree of diffuse atrophy of the cord can be present without adequate clinical symptoms — a situation quite analogous to that well known in brain where severe atrophy, manifesting itself by a marked communicating hydrocephalus, may be associated with disproportionately slight neurologic symptoms *The interpretation is easier* in circumscribed atrophy of the cord

SUMMARY

The typical position of the spinal cord within the membranous sac possibly derived from the close developmental relations between the neural tissue and the vertebral column is described The significance of the characteristic shape of the intervertebral foramina in predicting the depth of the ventral subarachnoid space is discussed It is shown that small thoracic disk protrusions with a narrow ventral subarachnoid space especially at the level of the lumbar intumescence may give rise to myelopathy

ZUSAMMENFASSUNG

Die typische Position des Ruckenmarkes in dem umgebenden Meningealsack die vermutlich durch die verwandte Entwicklungsgeschichte des Nervengewebes und der Wirbelsaule bedingt ist wird beschrieben Die Bedeutung der charakteristischen Form der Intervertebrallocher fur die Vorhersage der Tiefe des ventralen Subarachnoidalraumes wird erortert Es konnte bewiesen werden dass kleine thorakale Diskprotrusionen mit einem engen ventralen Subarachnoidalraum besonders auf dem Niveau der Lumbalschwellung die Ursache fur Ruckenmarksschadigungen sein kann

RESUME

L auteur décrit la position typique de la moelle epiniere dans l etui méningé due peut etre aux étroites relations de developpement entre le tissu nerveux et la colonne vertébrale Il examine l interet de la forme caracteristique des trous de conjugaison qui permet de prévoir la profondeur de l espace sous arachnoidien antérieur Il montre que de petites protrusions discales dorsales avec un espace sous-arachnoidien antérieur etroit en particulier au niveau du renflement lombaire peuvent causer une myélopathie

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diameter offers no difficulties The ventral subarachnoid space in a primary narrow cervical spinal canal is likewise narrow, or even slitlike unless a distinct degree of cord atrophy is present VERBIEST (1954, 1955) and EPSTEIN, EPSTEIN & LAVINE (1962, 1964) stressed the significance of a narrow lumbar spinal canal for production of disproportionately severe symptoms even with small protrusions

The investigation of the roentgenographic manifestations of the growth relations between the spinal canal and its content led to the conclusion that a *certain correlation* exists between the obliquity of the thoracic intervertebral foramina and the sagittal width of the ventral subarachnoid space or, in all probability, the sagittal diameter of the bony spinal canal Individuals with a lesser degree of sloping, i e with more horizontally oriented foramina, usually present a fairly wide ventral subarachnoid space This foraminal shape is found clear cut in children whereas in adults a more or less marked obliquity of the foramina is encountered (Fig 8) Even in younger subjects, however, the foramina may be oriented more vertically (Fig 9) When the obliquity of the foramina is extreme, they are usually also smaller in size, and the ventral subarachnoid space is narrow or slitlike (Fig 10) EPSTEIN, EPSTEIN & LAVINE (1964) recently reported that the height (i e the greatest sagittal diameter) of the lumbar intervertebral foramina gives an indication of the sagittal diameter of the lumbar spinal canal

Whenever the ventral subarachnoid space is or becomes abnormally narrow, the susceptibility of the spinal cord to damage from protruding discal and/or vertebral masses is enhanced (Figs 11, 12) Even in subjects with a sufficiently deep ventral subarachnoid space there exists however a *critical point* where this space is narrowed or even obliterated, i e at the level of the physiologic ventral bow of the cord, bringing the lumbar intumescence into close contact with the ventral wall of the spinal canal (Fig 1) A minimal *protrusion, on the borderline of the normal, and quite insignificant* in any other region, may here encroach upon the cord with possible untoward sequelae (Fig 11)

The pathologic entity known as *discogenic and/or vertebrogenic myelopathy* is obviously not confined to the cervical region only Many hitherto obscure spinal syndromes, even in the thoracic part of the spine, will probably find their natural explanation in this already *well defined* pathogenetic mechanism (STORTEBECKER 1960, ROMAGNOLI & TRABUCCHI 1963) A prerequisite for further progress in this field is, however, a still wider application of gas myelography with tomography, since minute *lesions* are *hardly* accessible to opaque myelography

FROM THE ISOTOPE RESEARCH LABORATORY AND THE CARDIOVASCULAR CLINIC, SODERSJUKHUSET, AND THE ISOTOPE TECHNIQUES LABORATORY, STOCKHOLM, SWEDEN

MEAN CEREBRAL BLOOD TRANSIT TIME OBTAINED BY EXTERNAL MEASUREMENT OF AN INTRAVENOUSLY INJECTED TRACER

by

S Hedlund K Ljunggren and V Kohler

Methods that furnish basic information on the cerebral circulation have been described in earlier investigations (8 11) The procedure of injecting labelled red cells into the two internal carotid arteries and sampling blood from the superior jugular bulbs gives the cerebral blood flow in ml/min A third injection of the cells into an arm vein and subsequent sampling from the jugular bulbs and one carotid artery makes possible the determination of the cerebral mean circulation time (MCT) and the cardiac output Furthermore the cerebral blood volume and the total blood volume of the body can be calculated Hence the cerebral circulation may be viewed in relation to the systemic circulation a comparison which is of hemodynamic importance

Although the method is very expedient the performance of a complete investigation is laborious It was therefore considered desirable to develop a simple screening test for the examination of the cerebral circulation that did not necessitate puncturing either the carotid arteries or the jugular bulbs One parameter has been chosen for the characterization of the cerebral circulation viz the cerebral transit time (CTT) which is defined as the time

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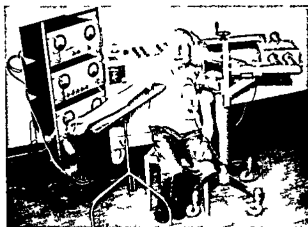


Fig 2 External measurement of the activity in the carotid artery and jugular vein from one side using separate detectors

portion of the carotid artery curve This overlapping is sometimes so great that the separation of the composite curve into an arterial and a venous phase will not be possible It has for this reason not been possible for about 20 per cent of all registered curves to obtain a measure of the transit time (9)

The diagrams of Fig 1 illustrate the reason for this phenomenon Corresponding carotid and jugular bulb curves recorded according to the sampling method have been superimposed both with the natural relative amplitude and with a reduction of the carotid curve relative to the jugular bulb curve in the ratio 1 2 and 1 3 The conditions prevailing in the actual measurement correspond approximately to the curve drawn in scale 1 2 From this it is clear that the measurement of both carotid and jugular bulb activity curves using one detector only may easily produce composite curves that cannot be evaluated to give a transit time

The method now presented is therefore based on the use of separate detectors for recording the activity time curves in the carotid artery and in the jugular vein It has been found advantageous to place one detector viewing the common carotid artery and the other over the mastoid region on the ipsilateral side It is important that the detector be placed precisely over the carotid artery and directed downwards so that activity returning from the brain via the jugular vein will not markedly influence the descending part of the activity curve due to the carotid artery In the same manner, the second detector must be centered over the mastoid region so that the parietal brain vessels do not contribute to the measurement which would give too low a cerebral transit time

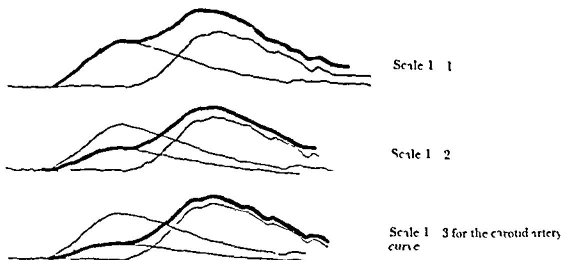


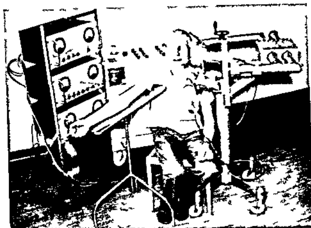
Fig. 1. Superposition of separately registered activity time curves from the carotid artery and the internal jugular vein. The conditions prevailing in the experiments correspond approximately to the curve drawn in scale 1:2.

difference between the maxima of the carotid and the jugular activity time curves. This time period can be determined by means of external measurement over the carotid artery and the mastoid region, following the injection of labelled red cells into an arm vein. This report deals with studies of an experimental method for determining CTT, including investigations of the relationship between CTT and MCT.

Methodology

The first method developed aimed at a determination of the transit time using only one detector (9). The measurement was made in the tangent plane to the condyli occipitales and the maxillar bone. In this plane, the internal carotid artery and the internal jugular vein run very close to each other and both vessels lie within the sensitive field of the collimated detector which is directed towards the vessels from the back of the neck.

However, this method of measurement suffers from a serious limitation. Since the active bolus of blood must pass through the cardio-pulmonary circulation before reaching the carotid arteries, a considerable dispersion in the direction of flow will result; the activity curve for the carotid artery will consequently be extended over a considerable period of time, about 10 seconds. The transit time sought is as a rule between 6 and 12 sec and this means that the initial part of the jugular vein curve will be superimposed on the tail



F g 2 External measurement of the act ty in the carotid artery and jugul r ve n f om one side using separate detectors

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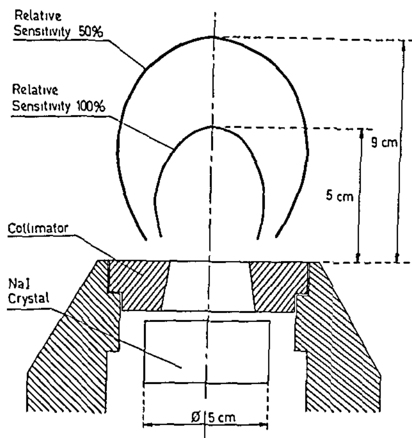


Fig 3 Relative response for the single bore collimator ([51]Cr source)

The measuring arrangement is shown in Fig 2 The detector assembly stand is specially designed for measurements on the patient's left side It has proved easier to obtain carotid recordings, the leading edge of which is not obviously obscured by contributions from the active bolus of blood during its passage towards the heart, if the injection is made into a vein on the right arm and the measurement is obtained on the left side of the neck The activity is measured by scintillation detectors with sodium iodide crystals of 2 diameter and 1 thickness The detectors are equipped with single bore lead collimators, the sensitive field of which is depicted in Fig 3 A single bore collimator *is preferable to a multi bore focusing collimator since it is* difficult to arrange the precise focusing, necessary for the efficient use of such a collimator, by means of external anatomical references alone

The detectors contain DuMont 6292 photomultipliers and preamplifiers whose outputs are connected to Ekco N 522 counting ratemeters

Both ^{131}I as the iodide and ^{51}Cr as chromate labelled erythrocytes were used for the measurements When ^{131}I was employed, the patient's thyroid had been

blocked by iodine administration for a few days before the investigation, in order to reduce the radiation dose

The measurements require about 1 μCi of ^{131}I for each kg of bodyweight, to produce peak counting rates of the order of 200 counts/sec Satisfactory speed and precision can be obtained in the curve tracing with a ratemeter time constant of 1 sec (8) Repeated measurements may be made with a somewhat increased amount of ^{131}I to compensate for the higher background resulting from the preceding injection Approximately ten times as much (i e 10 μCi/kg bodyweight) of ^{51}Cr is needed for a satisfactory result because of the lower γ ray abundance

The ratemeter discriminators are set at a value corresponding to about 300 keV in order to admit all counts contained in the main ^{131}I photo peak at 360 keV and the ^{51}Cr photo peak at 323 keV as well as to suppress radiation from adjacent vessels that has lost energy when being scattered within the detector acceptance angle The ratemeters are connected to a four channel ink jet recorder of the Elema Schonander Mingograf Cardirex 42 B type

One pair of experimental curves is given in Fig 4 The upper tracing is the carotid curve and the lower represents the activity variation in the jugular bulb It is evident that the leading edge of the carotid curve is somewhat distorted by contributions from the active bolus on its way to the heart This distortion can sometimes be larger The trailing edge of the carotid curve also contains elements from the activity variation in the venous system The only part of the carotid curve which with certainty is undistorted, and represents the activity variation in the carotid alone is therefore the portion around its maximum value The evaluation of the recorded curves has for this reason been based solely on the determination of the time difference between the appearance of the carotid curve maximum and the jugular bulb curve maximum (= CTT) The significance of this time index of the flow has been studied in a series of investigations that are reported below

Results

The cerebral transit time has been determined by the technique mentioned for 25 subjects in all The observed values ranged from 5 2 to 15 3 sec The investigated group comprised patients without any cerebrovascular disease and others suffering from hemiplegia dementia and chronic alcoholism No attention was paid to any variation in CTT between the different clinical group in this context since only the methodologic aspects will be considered

The examinations were organized so as to provide information on the reproducibility of the CTT determination and in addition on the influence if any of the position of the patient

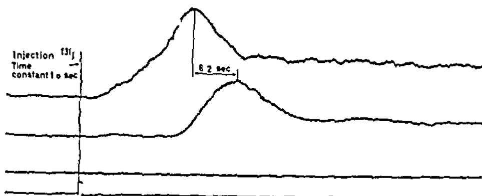


Fig 4 Activity time curves for the carotid artery (top) and the internal jugular vein (bottom) The CTT value is 6 2 sec (Ratemeter time constant 1 0 sec)

Two successive determinations on each one of ten seated patients were made The mean difference between the measured CTT values was calculated to be 0 8 ± 0 3 sec This may be regarded as an estimate of the mean error of the method if physiologic changes between repeat measurements are considered negligible

In eight patients, the CTT was determined with the patient first in the sitting position and immediately afterwards in the recumbent position Each pair of determinations gave values that agreed within the limits of error of the method

In six patients, two successive determinations were carried out in the recumbent position Again, the values in each pair of observations tallied within the limits of error of the method

It therefore seems safe to conclude that reproducible measurements of the cerebral transit time may be made by means of external measurements, either with the patient seated or recumbent It remains, however, to be proved whether the CTT value can be correlated to some entity that is truly representative of cerebral blood flow As the first step in such a procedure the authors made simultaneous determinations of the CTT by means of the external detector system and by means of sampling from the ipsilateral carotid artery and the internal jugular bulb The experimental technique used for recording the activity curves when continuous sampling of arterial and venous blood was employed has been described in detail elsewhere (8) The method permits of separate determination of the activity time curves in the two vessels, without any cross interference and, in particular, it permits accurate determinations to be made of the time co ordinate for the curve maxima The time lapse between the two maxima yields a reference value for the CTT which has been used for checking the results obtained by the external measurement The

Table

Comparison of cerebral transit time (CTT) with cerebral mean circulation time (MCT) using results obtained by the puncturing and sampling technique

	Mean circulation time (MCT)	Cerebral transit time (CTT)
Normal subjects	8.60 ± 0.28	8.78 ± 0.24
	1.59 (32)***	1.37 (32)
Hemiplegics	11.21 ± 0.89	10.40 ± 1.00
	3.31 (14)	3.74 (14)
Atherosclerotic dementia	12.88 ± 1.79	10.20 ± 0.53
	3.88 (9)	1.60 (9)
Schizophrenic dementia	10.36 ± 0.43	9.70 ± 0.40
	1.56 (13)	1.44 (13)

* The values are mean ± standard deviation of mean given in seconds
Standard deviation in seconds
** Number of cases

difference observed was 0.4 ± 1.3 sec, this is not significant ($P > 0.05$ for 6 subjects)

Finally the CTT has to be compared with the MCT which is a quantity strictly related to the cerebral blood flow (1) The MCT may most easily be depicted as the distance in time between the centroid of the carotid activity time curve and the centroid of a composite jugular activity time curve, to which the activity time curves from each of the two jugular bulbs contributes in proportion to the flow through it The CTT is as mentioned previously, the time interval between the peak values of the carotid and jugular activity time curves measured on the patient's left side For the comparison of CTT with MCT one normal group and one pathologic group (cerebral atherosclerosis with hemiplegia or dementia schizophrenic dementia) comprising 32 and 36 patients respectively were available A correlation test between CTT and MCT gave a coefficient of correlation of 0.49 ($0.01 > P > 0.001$) for the first and 0.67 ($P < 0.001$) for the latter group The residual standard deviation was calculated to be 1.3 sec for the normal patients and 2.3 sec for the pathologic group No significant difference was found between the subgroups of the pathologic group by an analysis of co variance

The MCT was larger than the CTT for all these groups but the differences were not proved significant for any one of them (see Table) The CTT values for normal males were determined to be 8.3 ± 0.2 sec This figure should also be valid as a normal value when the CTT is determined by external detectors as the methods have been shown to give compatible results

The contribution from the extracerebral circulation was investigated by administering known amounts of ^{131}I in two successive injections, one into the external carotid artery, the other into the internal carotid artery. One collimated detector was placed over the mastoid region. The position of the injection needle was verified by means of sampling from the internal jugular vein during the experiment. When the injection was made into the external carotid artery, no activity appeared in the internal jugular bulb.

The result was that a certain amount of activity passing through the extracerebral circulation gave a signal amounting to 70 % of the one that would have been obtained if the same activity had passed through the cerebral circulation. This means that the signal after an intravenous or common carotid artery injection will be about 30 % higher than would have been expected if the contribution from the extracerebral region had been neglected. These figures are approximate and liable to individual variation since only one subject has so far been investigated in this way. The calculations also assume a flow branching ratio between the external and the internal carotid artery of 1 : 2.

Discussion

The investigations favour the belief that the method is suitable as a simple and safe screening test for determination of the cerebral blood transit time. The precision is satisfactory as is shown by the results obtained after repeated measurements. The position of the patient (seated or recumbent) does not measurably affect the result. The use of the CTT value as a characteristic index for the cerebral blood flow is fully justified for all practical purposes, since it cannot be experimentally distinguished from the MCT value which is a fundamental quantity for describing this flow.

The experiments also show that the contribution from activity *in the* extracerebral circulation to the activity curve recorded over the mastoid region cannot be neglected. This contribution will, for obvious reasons, appear after common carotid artery and intravenous injections but not after internal carotid artery injections. Oldendorf (1962, 1963), Fazio et coll. (1963), and Love et coll. (1961) have ignored the contribution from these tissues, considering it probably insignificant when seen against the background of the highly vascular brain; the present results indicate that this may lead to a considerable underestimate of the radiation intensity. If an injection, supposedly into the internal carotid artery, is made in error into the common carotid artery, the amplitude of the recorded curve will be lower, by approximately 10 per cent. Confirmatory results have been reported by van den Berg & van den Drift (1963).

Changes in the extracerebral circulation may thus be misinterpreted as being changes in the cerebral region This phenomenon will however, not considerably influence the measurement of the peak interval between the activity curves for the carotid artery and the jugular bulb

As has been mentioned above the active bolus will be of a considerable length when entering the brain owing to the intermixing during its passage through the cardio-pulmonary circulation This effect was a serious limitation when one and the same detector was used for assessing the tracer concentration in both artery and vein With the present technique, this phenomenon will not affect the determination of the cerebral blood transit time for subjects with a normal heart volume Should the heart however be considerably enlarged the bolus will be so extended when it reaches the cerebral pool that difficulties will arise in recognizing the peaks of the activity curves registered over the carotid and jugular regions

The cerebral blood volume has been determined for a large number of patients suffering from different cerebral diseases viz chronic alcoholism schizophrenic dementia atherosclerotic and senile dementia and hemiplegias due to cerebral atherosclerosis (HEDLUND et coll 1964) The values determined were within the limits of the normal mean value which has been found to be 133 ± 7 ml (mean ± the standard deviation of the mean) Expressed as a percentage of the total blood volume the cerebral blood volume was 2 7 ± 0 2 per cent in normal cases and nearly identical values were obtained for the different groups of diseases mentioned The cerebral blood flow can thus be roughly estimated from the ratio of the known cerebral blood volume to the mean circulation time if this be determined It has also been shown that a significant correlation exists between the mean circulation time and the cerebral transit time With only a small error is it thus possible to use the cerebral transit time instead of the mean circulation time for estimating the cerebral blood flow

If this screening test indicates impaired cerebral circulation the patient may be referred for a complete investigation of the cerebral blood flow by puncturing and sampling techniques (HEDLUND et coll 1964 and NYLIN et coll 1961)

The present method is similar to the one described by WILCKE & ZEH (1963) in which one detector is placed over the neck and the other over the confluens sinuum Their values for the cerebral blood transit time agree with ours FEDORUK & FEINDEL (1960) who placed the detector over the neck determined the cerebral transit time as the difference between the carotid and jugular peaks as observed from the activity time curve

After injection of an ^{131}I labelled hippuric acid salt into an arm vein

OLDENDORF determined the time of entrance in the brain pool and the time of exit by plotting the first derivative of the amount of isotope seen in the brain by an external collimator detector system, the interval between these two times was taken as a measure of the mean cerebral transit time (OLDENDORF 1962, 1963)

The time interval between the arrival in the carotid artery and the venous system in the brain after an injection of the tracer into the carotid artery has also been determined by BELL & HERTSCH (1961), CRANDALL & CASSEN (1957), FAZIO et coll (1963), and VAN DEN BERG & VAN DEN DRIFT (1963) Their methods necessitate puncture of a carotid artery which is not as simple as the puncture of an arm vein

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SUMMARY

A simple screening test for the determination of the cerebral circulation time by external measurement of a tracer injected into an arm vein using detectors with single bore collimators is described Using previously established techniques it was possible to verify the results obtained and for all practical purposes to identify the cerebral transit time (CTT) with the mean cerebral circulation time (MCT)

ZUSAMMENFASSUNG

Eine einfache Übersichtsmethode fur die Bestimmung der Gehirnzirkulationszeit durch auswartige Messung eines in eine Armvene injizierten Tracers wobei Detektoren mit Einkanal Kollimatoren verwendet werden wird beschrieben Mit Hilfe einer fruher entwickelten Methode war es möglich die erhaltenen Resultate zu bestatigen und fur alle praktischen Zwecke die *Gehirntransitzeit (CTT) mit der durchschnittlichen* Zirkulationszeit zu identifizieren (MCT)

RÉSUMÉ

Les auteurs décrivent une épreuve simple pour la détermination de la circulation cérébrale au moyen de détecteurs mis en place avec précision munis de collimateurs à un seul trou Avec l'aide des techniques préalablement établies il a été possible de vérifier les résultats obtenus et identifier pour toutes mesures pratiques le temps de transit cérébral *(CTT)* comme le moyen du temps de circulation (MCT)

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Book reviews

LA RADIOGRAPHIE DES FORMATIONS INTRARACHIDIENNES MOELLE RACINES LIGAMENTS ENVELOPPES Journée du 23 septembre 1963, Strasbourg sous les auspices de la Fédération de Neurologie Publié par H Fischgold and A Wackenheim 221 pages 122 figures et 3 tableaux Masson & Cie Paris 1964 Prix 49 NF

These articles on the roentgenologic examinations of the spinal cord and its surroundings cover myelography with positive and negative contrast media angiography of spinal cord angiomas and vertebral phlebography Viewpoints on new contrast media are also considered

The greater as well as the most interesting part of the book deals with technical problems in myelography The two dominant methods of performing myelography i e with positive and negative contrast media, are compared and evaluated in the introduction as well as the conclusion JIROUT, *in dealing with the pneumographic demonstration of normal and ab*normal spinal arachnoidal structures as well as writers who consider normal and abnormal findings in the cervical region malformations in the sacral region and disk protrusions in the lumbar region all prefer gas myelography It is evident that this offers a better chance than positive contrast myelography of revealing pathologic conditions of the spinal canal

It is difficult to go into all the details of the various articles some of which are in French and some in English suffice it to say that many are of great value in giving new aspects on different diagnostic problems The book is excellently illustrated

The appearance of this volume is a sign of an increasing interest in roentgenologic procedures in the examination of the spinal cord and its surroundings In contrast to the opinion of the publishers of the volume the reviewer has always considered gas myelography *superior* to myelography with a positive contrast medium a view that has been further confirmed by reading this book

Bengt Liliequist

THE REDUCTION OF PATIENT DOSE BY DIAGNOSTIC RADIOLOGIC INSTRUMENTATION Edited by R D Moseley Jr & J H Rust Charles C Thomas Springfield Illinois *1964 Price 12 50* dollars

Selected papers and free discussions on radiation dose problems in the broadest sense from a colloquium of twenty nine highly qualified specialists in radiology physics and technology held at the University of Chicago 1962 are collected in this volume Image amplification and television used with different recording systems are specifically treated in relation to dose The collection *of items does not present a complete coverage of the subject and therefore* cannot be called a manual or a text book which the title might imply Short original papers introduce the reader to highly actual problems for instance considerations of protection applied to roentgen diagnostic procedures The book is a stimulating source of information for all interested in new techniques in diagnostic radiology and the levels of performance in the conversion of radiation into clinically useful information

Olle Olsson

ACTA RADIOLOGICA

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DENMARK FINLAND NORWAY AND SWEDEN

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RIGHT AND LEFT GONADAL VEINS

An anatomical and statistical study

by

N E AHLBERG O BARTLEY and N CHIDEKEL

The roentgenologic and anatomical appearances of the left gonadal vein were discussed by the present authors in two previous papers (1965) It was stated in the first paper that at aortography retrograde contrast filling of the left gonadal vein occurred in men as well as in women and this was considered in relation to the anatomical conditions present in an autopsy material An absence of valves or incompetent valves in the cranial portion of the gonadal vein existed in more than half of the cases equally divided according to sex Valves were more often absent in the men while the women more often had incompetent valves The width of the left gonadal vein was more closely analyzed in the second paper the mean circumference figures indicated that the ovarian vein was significantly wider than the spermatic vein and that pregnancy was a contributory factor in this difference The close relationship between pregnancy and permanent widening of the ovarian vein was discussed

HODGKINSON (1953) measured the width of the ovarian vein during operation in 8 pregnant women These measurements were made in 6 instances on the left side in one on the right and in one instance bilaterally in all of them the

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Table 1

Circumference of the right and left gonadal veins in the total material — mean values in millimetres

Sex	Gonadal vein	Total material			Without valves			With valves		
		Number	Circumference	S^2	Number	Circumference	S^2	Number	Circumference	S^2
♂	Left	30	8.3	1.48	12	8.6	1.13	18	8.1	1.65
	Right	30	8.8	3.03	7	8.0	2.57	23	9.0	2.98
♀	Left	54	10.1	12.10	8	12.3	8.69	46	9.7	11.67
	Right	54	10.3	8.26	3	8.3	0.28	51	10.4	8.36
Total	Left	84	9.5		20	10.1		64	9.3	
	Right	84	9.8		10	8.1		74	10.0	

ovarian veins were considerably wider than those in 8 women who were not pregnant. Any difference in width of the veins on the two sides was not stated since the veins on the right side were measured in only two instances.

Anatomical studies of the right gonadal vein have earlier been carried out by RIVINGTON (1873) and FAGARASANU (1938). The first mentioned author investigated 6 men and 4 women. The gonadal vein opened into the right renal vein in one case of each sex while in all the others it opened directly into the inferior vena cava. The gonadal vein was not examined for the presence of valves in the case in which the spermatic vein opened into the renal vein. In the other 5 male cases, a pair of valves was noted at the orifice to the inferior vena cava but in only one of the 4 female cases were valves found to *be situated at the termination of the vein at the inferior vena cava.* FAGARASANU reported that in 30 cases investigated, more than half lacked valves on both sides; there was no reference to the sex in his report. No anatomical investigation of the right and left gonadal veins in regard to width and the relation of the width to pregnancy has been found in the literature.

The present investigation concerns the anatomy of the right and left gonadal veins according to the site of their terminations as well as to the incidence of valves and their condition. The renal and gonadal veins run different courses on the two sides, and a comparative analysis has been performed to estimate a possible influence of the course of the gonadal veins on their width.

Material and Methods. The material consisted of 84 autopsy cases of 30 men and 54 women averaging 79 and 78 years of age, respectively. A block of tissue that comprised the inferior vena cava, the renal veins and the cranial

Table 2

Circumference of right and left gonadal veins in cases with classified valves — mean values in millimetres

Sex	Gonadal vein	Cases with valves			Competent valves			Incompetent valves		
		Number	Circumference	S	Number	Circumference	S	Number	Circumference	S
♂	Left	18	8 1	1 65	15	7 7	1 10	3	10 0	0
	Right	23	9 0	2 98	18	9 3	3 06	5	8 0	1 20
♀	Left	34	9 9	12 91	20	7 6	2 24	14	13 3	8 95
	Right	37	10 8	8 33	20	9 3	2 01	17	12 6	9 84
Total	Left	52	9 3		35	7 6		17	12 7	
	Right	60	10 1		38	9 3		22	11 6	

portion of both gonadal veins (at least 10 cm) was removed from each case The gonadal veins were examined for the presence of valves which, if found were classified as regards competence The circumference of the gonadal veins was also measured — For further details concerning the methods employed attention is drawn to our earlier reports (1965 a and b) in which most of the left gonadal veins reported in the present paper are included — Pressure measurements and an estimation of the valve condition were carried out in all the 30 male cases The condition of the valves on the left side was determined in 34 of the 46 female specimens and on the right side in 37 of 51 cases

Results

The right gonadal vein opened into the right renal vein in 3 of the men (10 %) and 4 of the women (7 %) while in the others it opened directly into the inferior vena cava caudal to the termination of the right renal vein The inferior vena cava in one female case was duplicated caudal to the left renal vein into which the left sided inferior vena cava opened The left ovarian vein in this case opened directly into the left inferior vena cava The left gonadal vein in all the other cases opened either into the main branch or into a caudal branch of the left renal vein

The mean values of the circumference of the gonadal veins in the total material and divided into groups with or without valves are presented in Table 1 It is evident that no statistically significant difference in the circumference of the right vein compared to the left was noted within the sexes except in the female group without valves in which the veins were wider on

Table 3

Relation between number of children borne and circumference of the ovarian veins — mean values in millimetres

Number of children	Number of cases	Mean circumference Left	Right	S² Left	Right
0	18	7.7	8.6	4.95	4.93
1	6	9.7	10.0	5.49	0.67
2	13	10.7	10.9	7.49	6.66
3	8	12.5	11.3	9.75	7.94
≥4	9	12.2	12.2	17.34	10.89

the left than on the right side. In this respect, however, the material is too small for definite conclusions.

A comparison of the sexes (Table 1) indicates that the left as well as the right gonadal veins in the women were significantly wider than in the men ($t = 3.46$ and 3.00, respectively) in the total material. The same was true as regards cases with valves ($t = 2.71$ and 2.59, respectively) and those without valves *on the left side* ($t = 3.39$). *Three women and 7 men had no valves on the right* side, the circumference being about the same in the two groups. The material is too small to permit statistical analysis.

Twelve of the men lacked valves *on the left and 7 on the right side, i.e.* 10 % and 23 %, respectively. The corresponding frequency figures for women were 14 % and 6 %. Valves were thus more often absent on the left than on the right side, in men as well as women of the present material, *but* the differences are statistically significant only in women ($u = 2.20$). If, however, the comparison is made on the whole material the difference becomes significant ($u = 2.02$). Valves were absent twice as often on the *left* as on the right side. The men lacked valves on both sides more often than women, the differences being statistically significant (left: $u = 2.70$, right: $u = 2.29$).

In Table 2 the mean circumferences of the gonadal veins, in millimetres, are presented for the cases with valves in which pressure measurements were made. Both sexes presented a highly significant difference in mean circumference between the right and left sides in the groups with competent valves, the right was wider than the left (men: $t = 3.20$, women: $t = 3.70$). No significant difference between the right and left sides within the sexes was found in the other groups. The ovarian veins are significantly wider than the spermatic veins in the total material (left: $t = 2.61$, right: $t = 3.00$). It is also evident that

Table 4

Relation between number of children borne and incidence of incompetent valves in ovarian veins

Number of children	Number of ovarian veins with classified valves		Percentage of incompetent valves	
	Left	Right	Left	Right
0 + 1	15	16	27	31
≥2	19	21	53	57

the mean circumferences of the gonadal veins on the respective sides in cases with competent valves are the same in the two sexes The sex difference in the total material is thus due to the cases with incompetent valves

The veins on both sides were significantly wider in women when the valves were incompetent than when they were competent (left $t = 6.53$ right $t = 3.98$) The number of men with incompetent valves was too small to permit comparisons The men had incompetent valves in 3 instances on the left and in 5 cases on the right side i e 17 % and 22 % respectively, the corresponding figures for women being 41 % and 46 % The differences between the sexes in this respect are almost significant (left $u = 1.76$ right $u = 1.88$) When the frequency of incompetent valves in women (44 %) is compared with the corresponding figure for men (20 %) the difference is statistically significant ($u = 2.56$)

The same valve condition in regard to presence absence or competence on both sides existed in 40 % of the men and 43 % of the women examined Thus if only one vein was investigated in a case no conclusion could be drawn as to the valve condition of the vein on the opposite side

Influence of earlier pregnancies on the circumference of the gonadal veins Information on the number of children borne was obtained in all of the 54 female cases (see Table 3) It was shown in an earlier report (AHLBERG et coll 1965a) that the left ovarian vein was widened in relation to an increase in the number of children borne up to and including two With more than 2 children no further increase was noted A highly significant difference in the mean circumference of the left ovarian vein was found when nulliparae were compared with multiparae (mean circumference 11 6 mm $S^2 = 11.77$ $t = 4.76$) in the present material On the other hand no significant difference was evident between nulliparae and primiparae, or between the groups of multiparae

Table 5

Valve condition in cases with valves on both sides

Sex	Number of cases	Both sides competent %	One side competent other incompetent %	Both sides incompetent %
♂	14	64	36	0
♀	32	38	44	18

with different numbers of children borne. The material in this study was however smaller than that in our earlier one (1965b).

Statistically significant differences did exist on the right side when the nulliparous group was compared with the other groups (1 child: $t = 2.26$, 2 children: $t = 2.61$, 3 children: $t = 2.42$, 4 children: $t = 2.96$). No significant difference, however, was noted between any of the groups with children. If the multiparous groups are combined, the mean circumference of the right ovarian veins was 11.4 mm and $S^2 = 8.56$. A significant difference ($t = 2.22$) was evident on comparison of these combined cases with the primiparous group. Thus, the width of the right ovarian vein also increases in relation to the number of children borne, up to two, as was earlier demonstrated for the left ovarian vein.

Estimation of the frequency of incompetent valves on both sides in relation to the number of children borne revealed no significant difference between the nulliparous and primiparous groups. The same was true when the multiparous groups were compared with each other. The nulliparous and primiparous groups were therefore combined and compared with the multiparous group (Table 4). It is apparent from the table that the frequency of incompetent valves is about the same on the left and right sides and that with multiparity

Table 6

Relation between number of children borne and valve condition in women with valves on both sides

Number of children	Number of cases	Both sides competent %	Incompetent on one side	Both sides incompetent %
0 + 1	14	57	29	14
≥ 2	18	22	56	22

incompetent valves occurred more often than in the other cases The material is too small to permit definitive conclusions on these differences, it was shown however that the frequency of incompetent valves on the left side was increased with multiparity in a larger material (AHLBERG et coll 1965b)

A comparison of the two sides in cases with valves in which pressure measurements were performed (Table 5), disclosed that 64 % of the men and 38 % of the women had competent valves bilaterally The difference is not statistically significant Competent valves on only one side occurred at about the same frequency in both sexes On the other hand no men and only 6 out of 32 women had incompetent valves on both sides two of these women were nulliparae while the others were multiparae

A division of the women with valves on both sides in relation to the number of children borne (Table 6) revealed that there is a higher frequency of competent valves on both sides in the combined nulliparous primiparous group compared to the multiparous groups (u = 2 03) In the last mentioned group a higher frequency of incompetent valves on one side is present as compared to the other group Incompetent valves occurred about equally often on the left as on the right side in both groups As may be seen from Table 6 the frequency of bilateral incompetence is about the same in the two groups

It was revealed in an earlier report (AHLBERG et coll 1965b) that even in the group with competent valves the width of the left ovarian vein was increased after pregnancy In the present study, the number of primiparae with competent valves is too small to permit definite statistical conclusions For this reason probably and in contrast to the earlier study no significant widening of the gonadal vein was noted in the group of primiparae Statistically significant differences were on the other hand evident between the nulliparous and multiparous groups The number of ovarian veins in each of these groups 8 and 12 respectively, was the same on the two sides On the left side the mean circumference in the group of nulliparae was 6 6 mm (S^2 = 0 67) and of multiparae 8 3 mm (S^2 = 2 19) Corresponding figures for the right side were nulliparae 8 5 mm (S^2 = 1 50) and multiparae 9 8 mm (S^2 = 1 70) (left t = 3 18 right t = 2 24) Thus, even in the group with competent valves the mean circumference of the ovarian veins was significantly increased on both sides with multiparity A comparison of the left and right sides in the group with competent valves indicated however that the right ovarian vein was significantly wider than the left (nulliparae t = 3 70, parae t = 2 31) It was previously shown (Table 2) that the right ovarian vein in the total material with valves was significantly wider than the left This difference exists even after division of the material according to the number of children borne

The possible influence of other factors on the width of the left gonadal vein, both individually and in combination with pregnancy, was discussed in our earlier work (1965b). Thus, age, the presence of cardiac insufficiency, and endocrine disturbances were not found to have any significant influence on the observed sex difference in width of the left gonadal vein. A similar distribution of these factors and the same results were recorded for the right side *in the present study.*

Conclusions

The present investigation has disclosed that valves are absent in the gonadal vein about twice as often on the left as on the right side and that men more often lack valves than women. Women more often than men have incompetent valves on both sides, and the width of the gonadal vein on both sides is greater *in women than in men.* The right ovarian vein, *as was shown earlier for the* left, is wider after pregnancy. The valves are more often incompetent in women with multiparity than in others. The right gonadal vein was in both sexes with competent valves significantly wider than the left. In women with incompetent valves, on the contrary, the left ovarian vein was somewhat wider than the right one but the difference was not significant. These facts may indicate that with parity the left ovarian vein widens more than the right. Except for these findings there has been no indication that the anatomical differences on the two sides have any influence on the circumference of the gonadal veins.

SUMMARY

The left and right gonadal veins were investigated in 81 autopsy cases consisting of 30 men and 51 women. Valves were more often absent in men than in women and both sexes more frequently lacked valves on the left than on the right side. Women more often than men had incompetent valves and wider veins on both sides. These changes were related to past pregnancies. There was no indication that the different anatomical courses on the two sides have any definite influence on the width of the gonadal veins.

ZUSAMMENFASSUNG

An 81 Leichen, von denen 30 männlich und 51 weiblich waren, wurden die Venen der *Gonaden studiert. Klappen fehlten häufiger* bei Männern als bei Frauen und beide Geschlechter zeigten häufiger klappenlose Venen auf der linken als auf der rechten Seite. Häufiger als die Männer hatten die Frauen funktionsuntüchtige und weitere Venen auf beiden Seiten. *Diese Veränderungen* wurden in Beziehung auf frühere Schwangerschaften gebracht. Es konnte nicht nachgewiesen werden, dass ein verschiedener Verlauf der Venen auf den beiden Seiten von Bedeutung für die Weite der Venen war.

RÉSUMÉ

Les auteurs ont examiné les veines gonadiques sur 30 cadavres d hommes et 54 de femmes Les valvules sont plus souvent absentes chez les hommes que chez les femmes et dans les deux sexes elles manquent plus souvent du coté gauche que du coté droit Les femmes avaient plus souvent que les hommes insuffisance valvulaire et des veines élargies sur les deux cotes Cette différence était conditionnée par des accouchements antérieures La différence anatomique de trajet des veines droite et gauches ne parait pas avoir d in fluence nette sur le calibre des veines gonadiques

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BIOMECHANICS OF THE CERVICAL SPINAL CORD

Relief of contact pressure on and overstretching of the spinal cord

by

ALI BREIG and AHMED FOUAD EL NADI

The choice of conservative or surgical measures in acute and chronic spinal cord injury will be determined largely according to the concept of how detrimental forces act mechanically on the cord Apart from compression, which has always been regarded of importance, workers of today tend to emphasize the significance of pathologically increased tension Many models have been designed as aids to the understanding of the problem but up to now the lack of knowledge of the mechanical properties and biomechanical behaviour of the hindbrain/spinal cord tissue tract has constituted a considerable handicap As new light has been thrown in recent years on some basically important features, this may perhaps enable the action of compressive and tensile forces to be seen in a more appropriate mechanical connection

A fairly common mechanism of damage in processes which encroach upon the width of the spinal canal is contact pressure on and overstretching of the spinal cord This has considerable practical implications For all stages of treatment of spinal cord lesions — from first aid, transport and operation to rehabilitation — further traumatic damage to the nervous tissue may be

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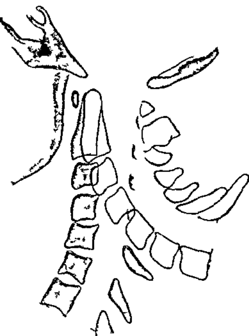


Fig 1 Extreme functional positions of a normal cervical spine in relation to the posterior fossa In ventroflexion (shaded) the cervical canal is elongated while in dorsal extension it is shortened (unshaded) the change in both instances being greater on the dorsal than the ventral contour

avoided by correct support of the spine so that the dura cord and nerve roots become slack The biomechanical basis of the necessary measures is outlined in this paper

The earlier view that the mechanical effect on the cord and nerve roots mainly consisted of compression has led to many neurosurgical and orthopaedic operations being regarded as more or less exclusively decompressive in their effects irrespective of whether they consisted in laminectomy division of dentate ligaments or removal of protrusions on the ventral contour of the spinal canal Compression of the cervical cord must be considered when the cervical canal has become narrow as a result of acute or chronic pathologic changes As will be shown below however mechanical conditions conducive to compression of the cord are fairly unusual and occur only when the canal is markedly narrowed A proper understanding of the mechanical process will enable the surgeon to predict the outcome of his conservative or operative measures

A study has been made of the mechanical action of protrusions in the cervical canal and their effect on the cord in extreme functional positions The results obtained may serve as a basis for determining the type of damage to the cervical cord most likely to result from this type of mechanical trauma

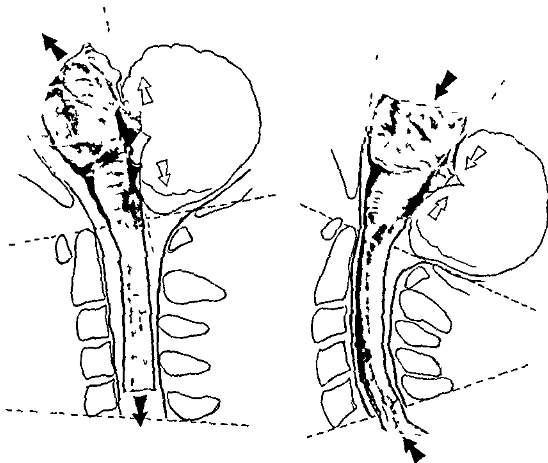


Fig 2 Longitudinal sections of two hindbrains with the cervical cords (fixed in situ) in relation to the foramen magnum and the upper cervical canal in full ventroflexion (left) and in full dorsal extension (right)

The mechanics of the hindbrain and the cervical cord are governed by the mechanics of the skeleton.

In *ventroflexion of the cervical spine, the functional axes of curvature of the* intervertebral and atlanto occipital joints are on the ventral side of the spine, so that its dorsal contour (Fig 1) will be slightly elongated. The clivus will in addition rotate forwards, which leads to a correspondingly increased distance between the occipital bone and the arch of the atlas.

In dorsal extension of the cervical spine the functional axes of curvature lie on the dorsal side of the spine and it is now the dorsal contour that undergoes the greater shortening. The clivus is rotated backwards and the angle between its upper contour and the posterior contour of the odontoid process decreases, often to 180° or less. The distance between the occipital bone and the arch of

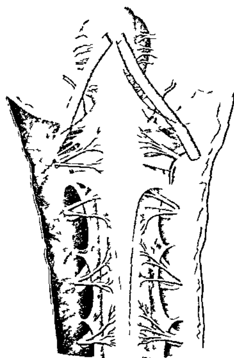


Fig 3 Hindbrain and cervical cord from the front A rhomboid arachnoid veil lies on the ventral aspect of the medulla and the upper part of the cervical cord (From KEY & RETZIUS Table 1 Fig 2)

the atlas also decreases perhaps to zero In extreme positions, the change in length of the ventral and dorsal contours is greater in the cervical than in other parts of the spinal canal In consequence it is the cervical dura and cord that display the greatest variations in length As a result of the shortening of the cervical canal in dorsal extension of the cervical spine with the head tilted backwards the cervical dura and cord undergo axial compression and hence shortening and slackening Since in this position the shortened cervical canal is often strongly curved backwards there may be a backward curvature of the axis of the pons the medulla oblongata and the upper cervical cord (Fig 2)

Measurements by means of indicators have shown that the floor of the fourth ventricle and the dorsal contour of the medulla are shortened in this position and that this leads to slackening of the hindbrain Confirmation has been obtained from autopsy specimens and at operations The resulting increase in mobility of the hindbrain and cervical cord is evident from the fact that these structures can be raised dorsad or moved laterally until the slackened dentate ligaments and nerve roots in the posterior fossa and cervical canal are pulled



Fig. 4. Tomographic gas myelograms of lower cervical spine and upper thoracic spine (left) and of upper cervical spine (right). The cord follows the curvature of the upper thoracic canal, whereas in the ventroflexed cervical canal it follows a straight path across the slight lordosis.

taut. This mobility may be exploited during operation in the region of the cervical cord and medulla or further rostrally in the region of the pons, as well as in the rest of the spinal canal, to obtain an easier approach to the ventral contour of the posterior fossa and the cervical, thoracic and upper lumbar canal without risk of injury to the hindbrain and cord.

The cord in its relaxed state may be deformed, for instance by surgical instruments, without impairing its conductivity. When the dura is sufficiently thin and translucent it is possible to follow the axial movements of the cord, medulla and cerebellar tonsils. These movements are synchronous with respiration and increase in amplitude with the degree of dorsal extension. During a particularly deep breath, the slack medulla and cord may be thrown dorsad by a fluid wave. Conversely, during ventroflexion these movements diminish until they are no longer visible in the extreme position. Synchronous pulsation movements have seldom been observed with the naked eye.

The intervertebral canals leave the cervical canal on its ventrolateral contour and in ventrolateral directions.

The attachments of the dentate ligaments to the dura in the cervical canal are located slightly dorsal to the exit of the nerve roots and slightly nearer the anterior than posterior aspect The most rostral ligaments arise in the lateral bands of the cord and run obliquely backwards and upwards to their dural attachments in the posterior fossa where they are located dorsal to the site of entry of the vertebral arteries (Fig 3) When the cervical dura is pulled taut in ventroflexion the tension exerted by the dentate ligaments is transferred axially and radially to the cord so that the cord becomes stabilized in the canal and kept away from the odontoid process by the most cranially situated dentate ligaments The rhomboid arachnoid veil (Fig 3) described by KEY & RETZIUS (1875) appears to have the same function If also the head is bent forwards the hindbrain will also be pulled taut, elongated and stretched between its fixation at the mesencephalon and the taut cord The angle between the upper contour of the clivus and the dorsal contour of the odontoid process will then increase and the supplementary ventral angle will decrease The occipital bone moves away from the atlas arch and the arches of the cervical vertebrae will spread The result will be a marked elongation of the atlanto occipital part of the upper cervical canal on its dorsal aspect and correspondingly of the dorsal contour of the medulla and the floor of the fourth ventricle the roof of which becomes more obtuse while the choroid plexus bulges less into the ventricle

It has been demonstrated at autopsy that dorsal extension of the cervical spine in the prone position causes the cord to sag to the ventral aspect of the cervical canal Dorsal extension in the supine position produces slackening of the dura and the dentate ligaments and allows the cord to come in contact with the dorsal aspect of the cervical canal Stretching of the dura the ligaments and the spinal cord in ventroflexion however, lifts the cervical cord away from the dorsal aspect of the canal so that it may come in contact with any protrusion present on the ventral aspect

The attachments of the dentate ligaments to the dura in the region of the thoracic canal are located more dorsally Gas myelography will therefore usually reveal the cord to follow the normal dorsal convexity of the thoracic canal nearer its dorsal than its ventral aspect (Fig 4)

The elastic stretching and relaxation of the tissue tract results *in a slight* axial displacement of the dura and the cord within the cervical canal This displacement differs slightly for the two structures consequently there is a slight displacement of the cord within the dura (SMITH 1956 BREIG 1964) These displacements being relatively small are of minor importance as compared to the large movements associated with elongation and shortening and will therefore be disregarded in the present connection



Fig 5 Case 1 Median sagittal tomographic gas myelograms in dorsal extension and full ventroflexion of cervical spine a) Dorsal extension The protrusion at C4—C5 bulges into the cervical cord b) Ventroflexion The cord is still in contact with protrusion in (a) but now the protrusion at C5—C6 bulges into the cord

Material and Methods Gas myelography was performed in 6 male patients with funicular signs suggestive of cervical myelopathy The examinations were conducted over a period of 5 months from October 1962 to March 1963 The roentgenograms were taken in full ventroflexion and dorsal extension of the cervical spine with the object of ascertaining which protrusions came into contact with the cord and thus were probably responsible for the symptoms and signs

General anaesthesia was used only in one uncooperative patient Premedication consisted of intramuscular administration of 25 mg Pethidin and 25 mg Phenergan 15 minutes prior to the examination

The patient was held in the lateral position with the cervical spine parallel to the roentgen table, the head end of which was lowered about 15° to 20° After combined cisternal and lumbar puncture, air was injected slowly through the lumbar needle and the cerebrospinal fluid was allowed to drip from the cisternal needle When all the fluid had been removed, and the subarachnoidal air pressure had been raised to between 200 and 300 mm H_2O by air insufflation



Fig 6 Case 2 Med n sag ttal tomog aph c gas myelograms in dorsal extens on and full vent o flex n of cervical spine a) Do sal extension The p otru ons at C3—C4 at C4—C5 and at C5—C6 bulge nto the cord b) Ventroflexion (n th s case patholog cally reduced) A well defined a r column l es along the ventr l contour of the co d except at the C3—C4 and C5—C6 levels

F g 7 Case 3 Med an sag ttal tomograph c g s myelograms in dorsal extens on and full ventroflex on of cerv cal sp ne a) Dorsal ex tension Fairly wide clea ance between the p otrus on C3—C4 and the cord b) Ventroflexion Contact between protrus on and co d present for a short d stance

under manometer control high kilovolt exposures of the cervical spine were made in extreme positions with the head first bent backwards and then for wards the chin drawn in and the cervical spine ventroflected For most of the patients at least five special tomograms were exposed in each of these extreme positions with the beam perpendicular to the cervical column The entire width of the cervical canal at the suspected level of the intervertebral space of the cervical or cervicodorsal regions was thus covered In an attempt to locate a probable protrusion more accurately the sequence and distances of the five tomograms for the cervical and cervicodorsal regions were fixed at respectively 1 cm and 0 5 cm to the right of the midline in the midline and 0 5 cm and 1 cm to the left of the midline It was considered that this would demonstrate any intraforaminal dorsolateral or dorsomedial protrusion

Results

All subjects (Figs 5 to 10 Cases 1 to 6) exhibited more or less advanced degeneration of the disks with marked reduction of the intervertebral spaces and osteophytes at the upper and lower margins of the bodies at various




a Fig 8 b




a Fig 9 b




a Fig 10 b

Fig 8 Case 4 Median sagittal tomographic gas myelograms in dorsal extension and full ventroflexion of cervical spine a) Dorsal extension The protrusion at C3—C4 bulges into the cord b) Ventroflexion There is still contact but over a smaller area

Fig 9 Case 5 *Median sagittal tomographic* gas myelograms in dorsal extension and full ventroflexion of cervical spine a) Dorsal extension Contact at the protrusion C4—C5 and bulging of the protrusion C5—C6 into the cord b) Ventroflexion There is a narrow air space between the protrusion at C4—C5 and the cord but now the protrusion at C5—C6 bulges farther into the cord (cf fig 5)

Fig 10 Case 6 Median sagittal tomographic gas myelograms in dorsal extension and full ventroflexion of cervical spine a) Dorsal extension The protrusions at C3—C4 at C4—C5 and C5—C6 bulge into the cord b) Ventroflexion A clear air space is evident along the ventral contour of the cord except at a more laterally situated small area of contact at the C4—C5 level and a distinct air space along the dorsal contour of the vertebral bodies

levels of the cervical spine These osteophytes, together with the disk protrusions sometimes bulged far into the cervical canal The flexibility of the cervical spine, as reflected in its extreme positions in the films was considerably less than in the normal subject It was nevertheless retained to the extent that the bulging of the dura into the lumen of the canal was more marked in

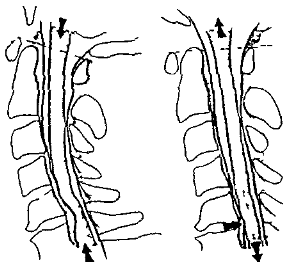


Fig 11 Diagrammatic representation of gas myelograms of Case 4 depicting the effect of the protrusion on the cervical cord in full dorsal extension (left) and in full ventroflexion (right)

dorsal extension than when the spine was in its normal position owing to the axial compression and ensuing relaxation of the dura and ligaments This is particularly well illustrated in Case 1

The relaxation of the cervical cord in dorsal extension was evident in all the tomograms as a wavy ventral and dorsal contour When the patient is in lateral position with the head end of the table tilted the caudal part of the cervical cord sags onto the sloping anterior contour of the canal and comes into contact first with the largest of the protrusions and then with any others Since in this position the effect of gravity on the cord is similar to that in the fully prone position it will be referred to simply as the prone position As several of the roentgenograms show the slackening may be so marked that the cord even drops onto the dorsal surface of the vertebral bodies that is, onto a fairly large area of the dura The increase in number of contact areas in dorsal extension is also due to the more marked bulging of the protrusions in this position When the head is bent backwards, the hindbrain together with the cranial attachments of the dentate ligaments are also slackened, and in consequence the pons and the medulla fall on to the clivus and the tip of the odontoid process Examples are provided in all cases excepting Case 3, in which the foot end of the roentgen table was probably tipped so that the slackened hindbrain under the influence of gravity fell dorsad

A difference in phase between the undulations on the ventral and dorsal contours produces the wavy pattern of the slackened cord The reason for this



Fig. 12. Dura stripped from the cervical canal to reveal the functional behaviour of the flaval ligaments in full dorsal extension and ventroflexion. After incision of the dura around the foramen magnum it was stripped from the surrounding attachments in the epidural space by means of long scissors and severed at C7.

is not clear but may possibly derive from the oblique force exerted by the nerve roots. The wavy dorsal contour is obviously not caused by the folding of the dura over the ligamenta flava, since in all cases except in Case 2 (perhaps because of arachnoidal adhesions) there was a clear air stratum in the subarachnoidal space between the dorsal contour of the cervical cord and that of the cervical canal.

The cross section of the cord normally increases in dorsal extension; in the present subjects this was not marked, though it was just evident in Cases 1 to 4 at the level of the atlas. Ventroflexion causes stretching of the dura and surrounding structures, including the dentate ligaments, and hence the spinal cord, and the bulging of the disks, the dura and the flaval ligaments into the lumen of the canal is distinctly diminished. Moreover, the lower part of the cervical cord in particular is 'raised' from the anterior surface of the canal. The stretching is manifest on the straight ventral and dorsal contours of the cervical cord (Cases 1, 3, 4, 5, 6); the area of contact between the cord and the protrusion(s) is thus reduced. Ventroflexion of the spine was pathologically restricted in Case 2, and as the cord was not much stretched its anterior contour retained its wavy form.

Stretching causes the cord to move away from the anterior surface of the

Table

Appearances in dorsal extension of the cervical spine (Cases 1 to 6)

Case	Decrease in angle between clivus and odontoid process*	Shortening of the upper cervical canal** (per cent)	Slackening of hindbrain and cervical cord — approximation of anterior contour of			
			Pons to clivus	Medulla to tip of odontoid process	Medulla to dorsal contour of odontoid process	Medulla to anterior contour of cervical canal
1	16	28	Evident	Evident	Evident	Marked
2	8	20	Just visible	Just visible	Just visible	Marked
3	10	27	Separation	Separation		Separation C3—C4
4	11	25	Evident	Evident	Evident	Marked
5	16	24	Just visible	Just visible	Evident	Marked
6	8	16	Evident	Evident	Just visible	Evident

* Since the clivus plane (the usual reference in measuring the angle between base of the skull and cervical canal) could not be recognized in all films, the dura on the upper surface of the clivus and on the dorsal contour of the odontoid process was used as reference.

** Since all the arches were not identifiable in the lower part of the cervical spine, only shortening between the occipital bone and the lower border of the arch of the epistropheus was measured.

canal and follow a straight course through the lordosis of the upper cervical canal. This is clearly demonstrated in the films (excepting in those of Case 2) by the good air filling of the subarachnoid spaces. Cases 1, 3, 4, 5 and 6 prove that the dorsal contour of the cord then approaches the posterior contour of the cervical canal at the level of the arches of the axis and the third vertebra. A distinct air layer in the subarachnoidal space on the dorsal contour of the cervical cord both in full dorsal extension and ventroflexion is, however, always present. This rules out the possibility of compression of the cord in all positions of the cervical spine in the cases referred to, because for a body to be compressed it must lie between two rigid surfaces that are approaching one another.

A stretched cervical cord loses contact with the anterior contour of the canal between spondylotic protrusions (Fig. 11). Conversely, dorsal extension in the prone position produces an increase in the area of contact between the cord and any protrusion, owing to more marked bulging of the dura and disk and slackening of the cervical cord.

Discussion

Functional roentgenograms The prone and supine positions cause the upper part of the cervical cord to be displaced ventrad and dorsad, respectively (JIROUT 1956) In addition, ventroflexion and dorsal extension cause the pons respectively *to approach and separate from the clivus*, and the cisterna pontis to narrow and widen As no account is taken of the position of the head and cervical spine *it is necessary to define the conditions more precisely* the displacement of the cervical cord, ventrad in the prone and dorsad in the supine position, takes place *only from the erect position to full dorsal extension of the* cervical spine The displacements of the pons towards the clivus in ventroflexion and *away from it in dorsal extension take place only in the supine* position or with the body erect and the cervical spine extended In the latter *instance the cord sags under gravity onto the dorsal surface of the cervical* canal Moreover, only in the supine position is there a widening of the cisterna *pontis in dorsal extension*

The cervical cord, according to DECKER (1957), is not rigidly attached to *the canal This is true so far as the anatomy is concerned but as regards function* the cervical cord in full ventroflexion is immovable in both axial and radial directions

It is obvious from our results that it is possible to predict fairly accurately *the mechanical behaviour of the hindbrain* and the cervical cord in various positions of the cervical spine and body postures

Evaluation of gas myelograms of the cervical cord must take account of the distance of the vertex of the protrusion from the anterior surface of the cord and the posterior contour of the canal It can furthermore usually be noted whether the protrusion just makes contact with the cervical cord or bulges into it These features are of doubtful value in the clinical assessment unless the position of the body and the degree of ventroflexion or dorsal extension of the cervical spine are considered and clearly defined This is obvious in view of the difference in size of the protrusions, the stretching of the spinal cord tract and position of the latter in various postures Hence, the pathogenetic significance of any protrusion can be assessed accurately only in full ventroflexion Irrespective of the posture, only in this position can an examination reveal which protrusion becomes a hypomochlion to exert contact pressure on the stretched cervical cord and overstretch it A protrusion that does not come in contact with the cord in full ventroflexion is of no pathogenic significance Conclusive evidence of this fact is provided by the presence of a gas strip between the ventral contour of the cervical canal and the cord As the roentgenograms show, stretching of the spinal cord tissue tract in full ventro

flexion may result in loss of contact with a relatively large protrusion to which a traumatizing action may have been ascribed On the other hand a small protrusion may still be the cause of neurologic signs even if a collection of gas in the subarachnoidal space in positions other than full ventroflexion may suggest that this is not the case Confirmation must therefore be obtained from functional roentgenograms in full ventroflexion

More than one protrusion may of course function as a hypomochlion if located laterally only part of the anterior contour of the cord can come into contact with it Tomographic films are therefore required

Explanation of unilateral symptoms may lie in a lateral contact pressure In all cases in this series excepting Case 2 gas myelograms in full ventro flexion demonstrated a clear strip of gas in the subarachnoidal space between the dorsal contour of the cervical cord and the canal According to the above definition the possibility of any compression of the cervical cord in this position can therefore be eliminated The absence of such a strip in intermediate positions or dorsal extension is not simply conclusive evidence of compression The conditions that may give rise to true compression of the cord are discussed below

Detrimental forces

Only forces set up by physiologic movements will be discussed

Contact pressure and axial tension In full ventroflexion when the pia is drawn out the nervous tissue of the cervical spinal cord is under axial and horizontal tension

In myelograms a layer of gas is seen along the free dorsal contour of the cervical cord whereas its ventral contour makes close contact with the protru sion This latter exerts a pressure on the contact area of the stretched dura and cervical cord (O CONNEL 1956 REID 1960) this contact pressure diminishes with the third power of the distance to the free dorsal surface of the cervical cord where it is zero (BREIG & MARIONS 1963) Hence one of the main forces causing cervical myelopathy is axial tension

The type of cervical cord injury due to contact pressure and overstretching was previously ascribed to compression of the cord (KAHN 1947) and considered as an anterior spinal cord injury (SCHNEIDER 1962)

Contact pressure and overstretching as a cause of traumatic damage to the cord is frequently confirmed by clinical experience Patients suffering from cer vical myelopathy due to spondylotic protrusions not seldom experience in creasing spasticity and sometimes exhibit Lhermitte s sign in ventroflexion

Neurologic signs by disturbance of the long motor and sensory pathways are rarely elicited in dorsal extension, however. In fact, urinary incontinence and spasticity are often relieved, as has been observed when the cervical spine has been immobilized in slight dorsal extension by osteosynthesis, thus reducing tension in the cord.

Since increased axial tension is set up also in the normal range of ventroflexion of the cervical spine it may be looked upon as causing continuous and unavoidable trauma. It is produced mainly by disk protrusions and long-standing changes in the bone. In the latter instance, muscular tension due to (weak) pain reflex is rarely noticed and, therefore, no effective protection exists against extreme movements of the head and cervical spine. Only in acute derangement of the cervical spine is effective blocking evident, and then it is difficult to assess the extent to which this may be due to subluxation, inflammatory oedema or the pain reflex itself. Nor is there any such protection against further damage by ventroflexion movements in the case of tumours lying on the ventral contour of the cervical canal (foramen magnum). That deleterious axial tension is not observed more frequently in spondylotic protrusions is due to the degenerative shortening of the spine, slackening of the dura (CLARK & ROBINSON 1956, REID 1960, BREIG & MARIONS 1963) and, as seen from the present material, also to restricted mobility of the cervical spine.

Attempts have been made to analyse the type of damage to the cervical cord from an examination of histologic changes. This is a difficult problem, for overlapping contact pressure, axial tension and radial tension, transmitted also by the dentate ligaments, all exist within the cord substance. Another complicating factor is the non-uniformity of the mechanical properties of the cord. That the grey matter around the central canal is more readily displaced axially than the white matter in the border zones of the cord was established by MCVEIGH (1923) in his cord crush experiments. This would explain the more severe damage to central areas of the cord (BUCY, HEIMBURGER & OBERHILL 1948, MAIR & DRUCKMAN 1953). This phenomenon obviously plays a still more decisive role in central cervical cord injury (SCHNEIDER 1962) due to true compression. In spite of these difficulties, BEDFORD, BOSANQUET & RUSSELL (1952) concluded from their histologic observations that when spondylotic protrusions are present the cord is most likely to be subjected to a tensile force.

Compression. True compression of the cord occurs when the canal is narrowed by an expansive process or by displacement of a fractured vertebra or arch which not only bulge into the cord but press it against the opposite wall of the canal. According to WOLF, KHILNANI & MALIS (1956) compression of the

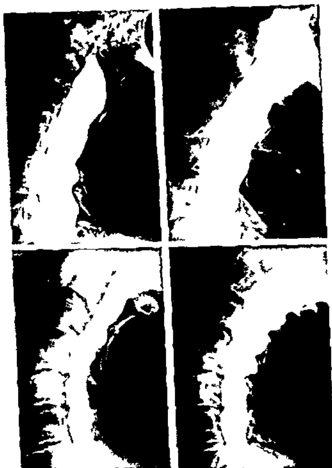


Fig 13 Demonstration of the cervical canal in the cadaver in dorsal extension after removal of the cord before removal of the dura (left) and after removal of the dura (right) (The level of the barium medium (top right) indicates the true horizontal)

cervical cord occurs when the anteroposterior diameter of the canal (measured from the lower border of a vertebra to the base of the opposite arch) *is less than* 12 mm Such a compression would seem to occur especially *in dorsal extension* when big ventral protrusions are present and folding of the flaval ligaments is accentuated

The impressions in the contrast medium evident in the cervical canal in dorsal extension are due primarily to more marked folding of the dura (Figs 12 13 and 14) These folds around the *canal are fairly* soft and can within limits be displaced axially as a stationary wave The impressions in the contrast

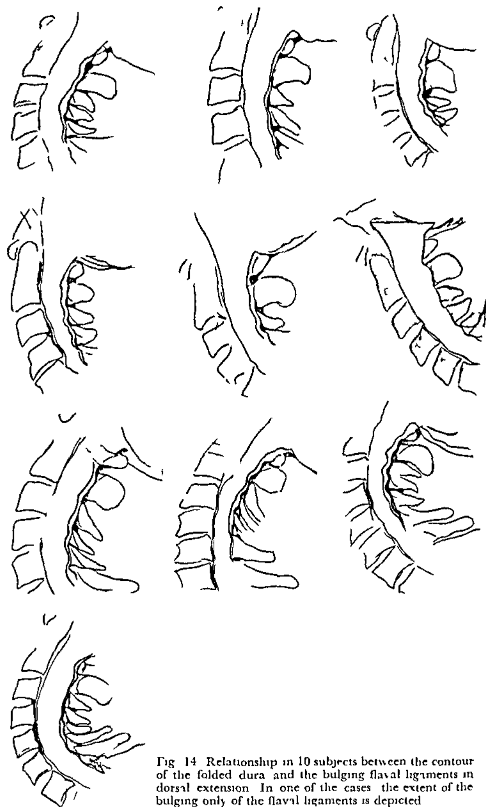


Fig 14 Relationship in 10 subjects between the contour of the folded dura and the bulging flaval ligaments in dorsal extension In one of the cases the extent of the bulging only of the flaval ligaments is depicted

medium will therefore be due chiefly to the folds of the dura and to a smaller extent to the flaval ligaments the bulging of which differs widely from one case to another Both the dural folds and the flaval ligaments are normal structures The dural folds can obviously be ruled out as a factor in the com pression mechanism because they are in themselves yielding More space is often available for the cord within the canal than is depicted by gas or positive contrast myelography Moreover, it should be borne in mind that in dorsal extension the cord is fully slackened and thus can adapt itself to any changes in shape of the cervical canal and the soft tissues a property that in some measure constitutes a protective mechanism against compression

There is no doubt however, that in processes encroaching on the canal the cord must ultimately be compressed between the pathologic protrusion and the opposite wall of the canal which can consist of part of the arches and/or the flaval ligaments This is most likely to happen in full extension when the canal is narrowed by bulging disks and ligaments and the cord is widened In fact not only in the above cases with a wide canal but also in those in which the canal is greatly narrowed by pathologic protrusions a strip of gas is invariably visible along the dorsal contour of the cord in slight to full ventroflexion This is conclusive evidence that compression of the cervical cord can never occur during ventroflexion since in this position the cord diameter is narrowed by stretching and the canal is widened by elastic stretch ing of the ligaments and the dura

True compression of the cervical cord by spondylotic protrusions in full ex tension may be caused by a combination of conditions a wide canal and extremely large protrusions a wide canal large protrusions and bulging flaval ligaments an extremely shallow canal and small protrusions a shallow canal small protrusions and bulging flaval ligaments

Whether a relation invariably exists between the diameter of the cord and the lumen of the canal remains to be determined If the cord should be dis- proportionately large or the lumen of the canal disproportionately small the presence of even a small protrusion would give rise not only to contact pressure on and overstretching of the cord in full ventroflexion but also to its compression in extension No means of demonstrating compression for example with a contrast medium has existed to date so that the presence of repeated compression trauma might be inferred from (1) indirect evidence (2) absence of a gas strip between canal and cord in the neutral position of the cervical spine or (3) when a positive contrast medium is used possibly from an observed arrest in this position Whereas the deleterious action of the forces is clearly manifest in full ventroflexion in the gas myelogram the mechanism is no longer apparent between neutral position and full dorsal

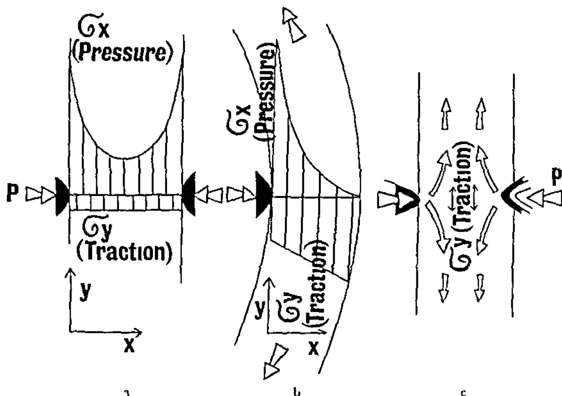


Fig 15 The mechanical stress on the cervical cord under different static and dynamic conditions true compression (squeezing) (a) contact pressure and axial tension due to bending (b) and sudden repulsion by a blow (c) The static forces obtaining in (a) and (b) have been discussed elsewhere (BREIG & MARIONS 1963) Under the dynamic conditions prevailing in (c) a sudden trauma of the cord due for instance to a bulging disk and/or a simultaneous forward bending of the spine would *cause a sharp displacement of the cord tissue The rapid movement (acceleration) of the cord* tissue within the pia would set up an axial tension which might result in tearing Conditions in (a) and (c) are statically similar Compare the tensile stress

extension Only from further narrowing of the canal and widening of the cord through axial compression can it be inferred that the cord is subjected to a deleterious (horizontal) compressive force that ultimately must lead to dislocation of nervous tissue in axial directions (see Fig 15)

When the canal is greatly narrowed, irrespective of its cause, and the cord, being entrapped within a segment of the cervical canal, can no longer escape trauma in dorsal extension through the yield of the slackened nervous tissue, double trauma may occur In ventroflexion, the cervical cord is damaged by contact pressure and overstretching, and in dorsal extension it is injured by true compression A somewhat analogous situation occurs for a cervical nerve root in the lateral section of a critically narrowed intervertebral foramen in full dorsal extension In contrast to this, the foramen in full ventroflexion is widened and the nerve root is damaged by contact pressure on and overstretching by a ventral protrusion In the case of ventral protrusions into a

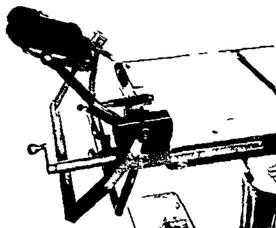


Fig 16 The Breig adjustable head rest (manufactured by AB Stille Werner Stockholm) As the cervical spine is elongated during ventroflexion and shortened during dorsal extension the position of the head rest is adjusted automatically so that the head and spine follow a normal pattern of movement

canal of normal width it is therefore necessary only to avoid ventroflexion movements whereas marked ventroflexion and dorso extension must be avoided in the case of protrusions into a greatly narrowed canal

Alleviation of tension in the damaged cord When an artificial tensile stress is added to the increased axial tension of the spinal cord tissue set up by pathologic processes the limiting strength of the cervical cord (the axons) may be suddenly exceeded with inevitable aggravation of the cord damage In the usual traction treatment for spinal injury such as compressive fractures fracture of the odontoid process and disk hernia prime consideration must be given to the mechanical effect on the spinal cord tissue In a case of damage to the cervical cord therefore an attempt must be made at the earliest possible moment to reduce the tension in the cord by reclining the head It follows moreover that in the reduction of a spinal fracture and the treatment of a disk protrusion the cervical spine should be placed in slight dorsal extension In fact certain types of fractures may be reduced spontaneously merely by placing the neck on a soft round bolster which induces this position Five cases of fractures of the odontoid process have been treated successfully in this way In cases of damage to the cervical spinal cord the primary neurologic signs are often so prominent as to mask secondary damage to the cord

As regards surgical treatment it is self evident that the best results are obtained when it is directed to the cause of the damage for instance by extirpation of bone fragments, protrusions or expansive lesions Such operations are greatly facilitated if the cervical cord and nerve roots are slackened by placing the cervical spine in dorsal extension a position that may be

effectively obtained by means of a special head support (Fig 16) The effect of other surgical procedures — commonly but often erroneously referred to as decompression — that have been found to be of practical value is often not decompression, or at least not only decompression For instance, laminectomy, which is decompressive in effect if there is true compression, often results also in a change in shape of the cervical spine or restriction of its range of mobility The possibility of overstretching of the spinal cord and the nerve roots is thus often reduced It can in fact be deduced from these sequelae of laminectomy — demonstrated best in postoperative films in extreme ventroflexion position — that there must be a limit to the degree of stretching of the spinal cord and the nerve roots

To give an example decompression is considered to be the effective factor in SCOVILLE's (1961) bilateral facetectomy Laminectomy, as the first step in the course of this operation, is of course, the usual means of eliminating any compression However, *from the widening and backward bulging of the dura* that invariably results after laminectomy also in the absence of compression, *it cannot be inferred that compression was present before laminectomy Nor* does this feature indicate a dorsal displacement of the whole dura, the anterior part of which is of course *still* attached to Trolard s fascia and the anterior longitudinal ligament The bulging of the dura is simply due to the hydrostatic pressure of the cerebrospinal fluid It is therefore more marked in the seated than in prone posture In Scoville's operation bilateral facetectomy is performed after laminectomy In effect, bilateral facetectomy would appear to eliminate the supporting action of the intervertebral joints so that the vertebrae are tipped into dorsal extension, with consequent slackening of the dura, cord and nerve roots

Restriction of the range of mobility of the cervical spine can be obtained also by osteosynthesis of the cervical spine, a technique introduced by CLOWARD (1958) *with the object of restoring the intervertebral distance*, with or without previous extirpation of bony or disk protrusions This measure, too, often results in relaxation of the cord and the nerve roots Essentially, the effect of this method, in which two adjacent vertebrae are fixed, *often* at an angle to each other, is either to eliminate the possibility of overstretching or *to produce a permanent slackening of the dura* and cord and hence a reduction of the tension

The beneficial effect on the hindbrain spinal cord tract of any spinal operation that changes the functional relation between soft tissues and the skeletal framework can be properly understood only through a fundamental study of the biomechanical functioning of the system From such an analysis, principles for both conservative and operative treatment might be drawn up

Acknowledgement

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SUMMARY

Examinations of six patients with myelopathy due to protrusions in the cervical region by gas myelography in prone position and full ventroflexion and dorsal extension are described Many so-called compression injuries to the cervical cord are due to contact pressure and overstretching as a result of tensile forces caused by protrusions By placing the cervical spine in extension a reduction in tension is obtained and provides optimal conditions for recovery

ZUSAMMENFASSUNG

Sechs Patienten mit Myelopathie infolge von Protrusionen in der Zervikalregion wurden mittels Gasmyelographie in Bauchlage bei optimaler Flexion und Extension der Halswirbelsaule untersucht Viele sogenannte Kompressionsschaden des Halsmarks entstehen durch Kontaktdruck und Überstreckung als Folge von Zugkraften welche von den Protrusionen erzeugt werden Lagerung der Halswirbelsaule in Extensionsstellung reduziert die Spannung und schafft eine der wichtigen Voraussetzungen fur eine Wiederherstellung

RÉSUMÉ

Description de l examen par myélographie gazeuse en procubitus et flexion et extension complètes de 6 malades atteints de myélopathie due a des saillies de la face antérieure du canal rachidien dans la region cervicale Beaucoup de lésions de la moelle cervicale attribuées a la compression sont dues a une pression par contact et a un étirement résultant de tension causée par ces protrusions L extension du rachis cervical diminue la tension et donne les meilleures conditions pour la guérison

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ROM THE NEURORADIOLOGIC DEPARTMENT (DIRECTOR PROF T GREITZ) KARO
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DILATATION OF CEREBRAL VEINS DURING CEREBRAL ANGIOGRAPHY WITH WATER-SOLUBLE CONTRAST MEDIA

by

T GREITZ

Experimental investigations on the influence of contrast media upon the
rebral circulation were initiated as early as in the 1940 s Judging from the
erature opinions still differ as to the effect of these media on the intracranial
ssels At first they were considered to cause vasospasm (HOLM 1944 BROMAN
OLSSON 1948 FOLTZ THOMAS & WARD 1952) although this could not be
nfirmed by authors such as BASSETT et coll (1953) BLOOR et coll (1954)
ROWNE & STERN (1954) and SCHMIDT (1955) made photographic records
rough a Forbes window in cats and rabbits and observed no contractions
though high concentrations of contrast media such as Joduron Perabrodil
nd Urografin produced vasodilatation INGVAR & SODERBERG (1957)
corded the venous outflow from the superior sagittal sinus in cats They found
at Umbradil 35 % reduced the flow and believed this could be due only to
asoconstriction KÅGSTROM LINDGREN & TORNELL (1958) demonstrated in
xperiments in cats that all water soluble contrast media used in cerebral
ngiography may produce an increase of up to several hundred per cent in

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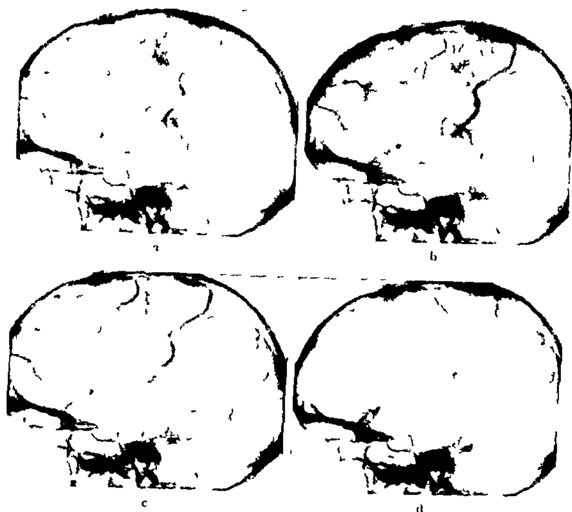


Fig. 1. Carotid angiography with 5 ml Urografin 60 %. Progressive widening of most cerebral veins.

cerebral blood flow. These authors considered this to be due to vasodilatation. TAVERAS & WOOD (1964) stated "there appears to be agreement that the injection of contrast substances is followed by a vasodilatation lasting a variable period of time, although some contradictory opinions have appeared in the literature". HILAL (1964) found no dilatation of intracranial vessels in connection with carotid angiography.

Materials and Methods. Seventy five cases in which carotid angiography had been performed with two different contrast media have been reviewed with the aim of studying possible calibre changes in the intracranial vessels at cerebral angiography. In 50 consecutive cases, 4 ml Triurol 50 % (sodium acetrizoate) had been used, and in 25 consecutive cases 5 ml Urografin 60 %



Fig 2 Detail of fig 1 a and c The sharply outlined vertically running frontal vein (arrows) is dilated

(a mixture of sodium and methylglucamine salts of diatrizoate) had been injected The cases examined with Triurol were manually and those examined with Urografin automatically injected The mean injection time was approximately a second regardless of the technique of injection Rapid serial angiography was performed in all cases the standard program being two films/second for 5 seconds and one film/second for 10 seconds Conclusions were mainly drawn from observations on the lateral views Calibre changes were also observed and checked in the antero posterior projections and the calibre could be measured directly on the film at least as regards the larger veins An ECG and a simultaneous record of the roentgen exposures were obtained in all cases A more clear concept of the degree and duration of the calibre changes was obtained by measurements made in the lateral projection of the diameter of two superficial veins one frontal and one parietal and one deep vein usually the internal cerebral vein These measurements were performed with an ordinary transparent ruler An attempt was made to measure the diameter to one tenth of a millimeter Care was taken that exactly the same cross section of the vein was measured in the different films and that the order of the serial films was quite arbitrary and unknown to the examiner It was obvious from initial random sampling measurements that all cases examined with Triurol had venous dilatation and thus only 10 cases were

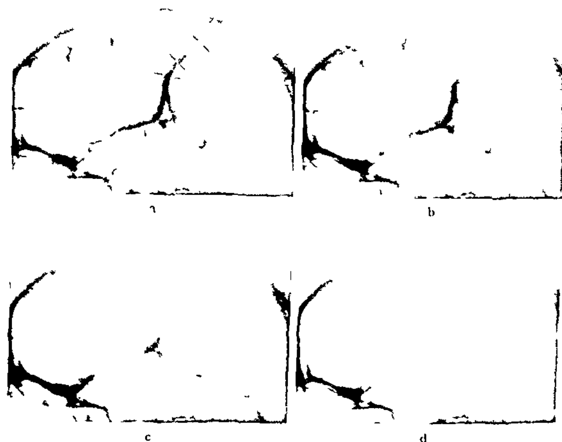


Fig 3 Carotid angiography with 4 ml Triurol 60 %. Exposures at 4, 5, 6 and 7 sec after maximum filling of carotid siphon. Measurements of parietal vein have been made at six different levels as indicated in (a) and the results are given in fig 4; most values obtained from the measurements on (a) are considered uncertain due to laminar flow with layer formation.

subjected to complete analysis. The changes incident to examinations with Urografin, however, were more subtle in degree and less frequent, and all the 25 cases in this group were therefore analysed.

Results

No definite dilatation of the cerebral arteries could be observed during the passage of contrast medium. Dilatation was however usually observed in the cerebral veins, both superficial and deep (Figs 1, 2 and 3). No calibre changes were evident in the deep dural sinuses. The cerebral veins generally start to fill 2 to 4 sec after the commencement of injection and achieve maximum filling 1 to 3 sec later, during which period a successive dilatation of the veins occurs and may continue for a further period of 2 to 3 sec. Dilatation was consequently evident for 3 to 6 seconds, which usually coincided with the

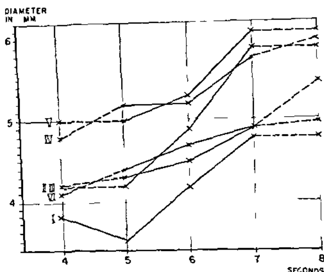


Fig 4 Results of measurements in fig 3 Roman numerals indicate levels of measurements from bottom to top broken lines record changes in calibre considered uncertain either due to layer formation or poor filling

time the vein was sharply outlined No further widening occurred at 3 to 4 sec after a vein had achieved maximum filling even in cases with prolonged filling so that determination of the calibre was possible for many seconds This dilatation was seen both in the lateral and a p projections and was evident in all the sixty cases in which Triurol had been used although it was not evident in every individual vein No definite calibre changes could be observed in any vein in five of the 25 cases in which Urografin was used In the ten cases examined with Triurol in which measurements were made the maximal dilatation recorded in an individual vein corresponded to 28 % increase of the diameter The mean dilatation based on 30 measurements was 11 % With Urografin the corresponding figures based on 75 measurements in 25 cases were 28 % and 6 %

Discussion

Measurements made of cerebral veins as a rule revealed an evenly increasing diameter as contrast medium flowed through their lumen This increase could in most instances be followed step by step in tenths of millimeters as measurements were made in a series of films and could be demonstrated at different locations of one and the same vein as seen in Fig 3 These facts make it

unlikely that laminar flow and layer formation between blood and contrast material are responsible for the changes in diameter, as measured on the films Such a layer formation may occassionally occur in the cerebral veins and could always be recognized because the lateral films were obtained with a horizontal beam direction Furthermore, care was taken only to measure the sharply outlined vein No layering was observed in the frontal veins running vertically upwards in the frontal region (see GREITZ 1954), but an increase in diameter could be noticed even in these veins (Fig 2) The caliber changes were, furthermore, observed in all the lateral as well as in the antero posterior projections They could be observed also when a vein was viewed along its axis and continued even after maximum filling of the veins had been attained *The dilatation can therefore not be explained as an optical illusion caused by less dense filling of the veins in the beginning of the venous phase* In fact, there appears to be little doubt that water soluble contrast media, when injected into the cerebral arteries, cause a dilatation of intracranial veins and that this dilatation may be observed at cerebral angiography

SUMMARY

Water soluble contrast media used for cerebral angiography cause a dilatation of intra *cranial veins The dilatation starts during the venous filling phase and* continues for a few seconds after the veins have attained maximum filling It seems to be more frequent and more marked following the injection of sodium acetrizoate than with methylglucamine sodium diatrizoate

ZUSAMMENFASSUNG

Wasserlosliche Kontrastmittel wie sie zur Gehirnangiographie benutzt werden verursachen eine Erweiterung der Gehirnvenen Diese Erweiterung beginnt wahrend der venösen Fullungsphase und dauert fur einige Sekunden nach der maximalen venosen Fullungsphase an Dieses Phanomen ist haufiger und mehr ausgesprochen nach Injektion von Acetrizoat als von Methylglucamine Natriumdiatrizoat

RÉSUMÉ

Les moyens des contraste hydrosolubles utilisés pour l angiographie cérébrale dilatent les veines intracraniennes Cette dilatation commence pendant la phase de remplissage veineux et se poursuit pendant quelques secondes après que les veines ont atteint le maximum de leur remplissage Cette dilatation semble plus fréquente et plus marquée après injection d acétrizoate de sodium qu apres diatrizoate de méthylglucamine sodium

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FROM THE DEPARTMENTS OF RADIOLOGY AND OTOLOGY AT THE COPENHAGEN COUNTY HOSPITAL, GENTOFTE, AND AT THE UNIVERSITY HOSPITAL OF COPENHAGEN, DENMARK

TOMOGRAPHIC CHANGES IN OTOSCLEROSIS

by

S BRUNNER, H ROVSING and J JENSEN

Thanks to present day precision tomography the anatomical details of the inner ear can be demonstrated radiologically with a fair degree of certainty Morbid conditions of the ossicles can also be demonstrated (BRUNNER, PETERSEN & STOCKSTED 1961)

After MUNDNICH s preliminary report, at the Congress of Otorhinolaryngology in Paris in 1961, on tomography of the oval window in otosclerosis, we introduced preoperative tomography of this region and a number of otosclerotic patients have now been subjected to this examination

Clinically, otosclerosis is characterized by slowly decreasing auditory function, often starting at the age of 20 and occurring twice as frequently in women as in men Between 10 and 20 years after the onset of the first symptoms the impairment in hearing may be considerable A bilateral conductive hearing loss occurs in 90 % of cases Other symptoms are tinnitus and dizziness but there is no pain

The original paper was presented at the Seventh Symposium Neuroradiologicum New York 1964 Submitted for publication 25 January 1965

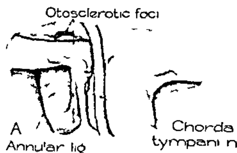


Fig 1 Lateral view of middle ear cavity during operation for otosclerosis The tympanic membrane has been removed to show the medial wall of the tympanic cavity with the long process of the incus lying horizontally connected with the stapes at the incostapedal joint The limbs of the stapes are seen pointing toward the oval window the edges of which are blurred by otosclerotic foci (Courtesy of SHAMBOUGH Surgery of the ear Saunders Philadelphia 1959)

The labyrinthine capsule consists of compact bone the labyrinthine part being derived from endosteum and the tympanal part from periosteum Between these two parts is the enchondral layer in which the well defined otosclerotic plaques appear Foci around the oval window grow slowly and may involve the annular ligament extending past the base of the stapes and fixing it in the oval window so that hearing impairment results (Fig 1)

The oval window which according to FISHGOLD s studies of anatomic preparations measures 3 0 to 3 5 by 1 0 to 1 5 mm is situated in the medial wall of the tympanic cavity forming an opening into the vestibule at the bottom of a funnel shaped depression called the fossula fenestrae vestibuli

When viewed from the lateral aspect this depression is localized supero anteriorly on the lateral vestibular wall while the fossula and the round window are situated infero posteriorly on the same bony wall Posteriorly the oval window is delimited by the anterior limb of the lateral semicircular canal and anteriorly it adjoins the basal part of the cochlea (Fig 2)

We have demonstrated the oval window on an anatomic preparation by inserting a gold cast of the stapes into it (Fig 3) (BRUNNER PETERSEN & STOCKSTED 1962)

Present investigation

Technique We have used anteroposterior tomography as a standard investigation employing Massiot s polytome with hypocycloid movement The tomographic cuts were at a mutual distance of 0 5 mm corresponding to the region around the oval window Six consecutive cuts show the window in its antero posterior extent The plane of the window coincides approximately with the

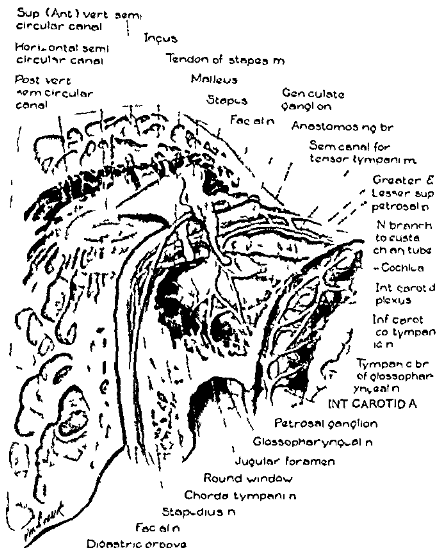


Fig 2 Sagittal cut through temporal bone showing anatomical details related to the oval and round windows (Courtesy of SHAMBOUGH Surgery of the ear Saunders Philadelphia 1959)

sagittal plane Cuts dorsal to the middle of the oval window also show, more caudally, the round window which, however, is less well defined owing to its rotation in relation to the sagittal plane (Fig 1)





Fig 3 Tomogram of an anatomic preparation with a gold cast of the stapes inserted into the oval window demonstrating the exact site of the window 1 External acoustic meatus (I — incus S — stapes) 3 — tympanic cavity

It should be mentioned that as a rule the stapes is not discernible in tomograms from normal subjects owing to the small size and low calcium content of this bone

Our material now comprises 15 patients with bilateral otosclerosis Out of 30 possible cases the diagnosis was confirmed surgically in 19 eight cases in the left and eleven in the right ear We have attempted to classify the operative findings into 3 groups according to severity as recorded in the Table on p 636

The series includes 10 cases of surgically confirmed fairly mild otosclerotic changes and 9 cases with more severe changes In the former group the radiographic results were in keeping with the surgical findings in 8 out of the 10 cases while one case was radiologically normal and one showed more severe tomographic changes

In the group with severe surgical changes radiography also showed severe changes in 7 out of the 9 cases while only mild changes were found in 2 cases In other words there was conformity between the operative findings and the tomographic appearances in 15 out of 19 tomographed cases Two types of characteristic changes were distinguishable in the tomograms of the patients with otosclerosis One type of change consisted in a very narrow fenestral opening it being almost as thin as a needle and with distinctly denser edges (Fig 5) Such a narrowing of the window presented itself only on two or three

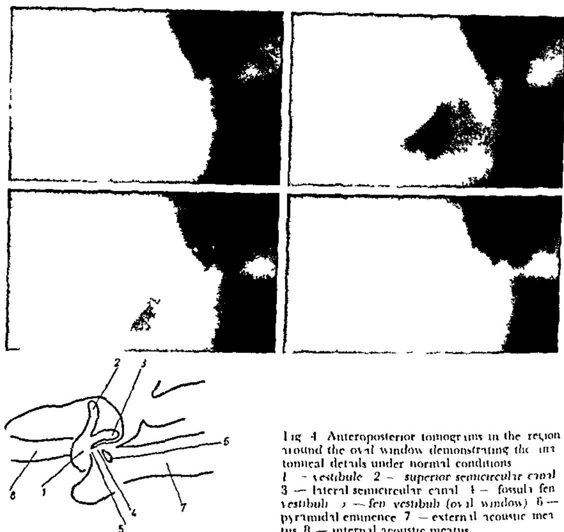


Fig. 4. Anteroposterior tomograms in the region around the oval window demonstrating the anatomical details under normal conditions.
1 — *vestibule*. 2 — *superior semicircular canal*. 3 — lateral semicircular canal. 4 — fossula fen. vestibuli. 5 — *fen. vestibuli* (oval window). 6 — pyramidal eminence. 7 — external acoustic meatus. 8 — internal acoustic meatus.

Table

Surgical findings	Tomographic changes		
	Normal	Mild changes	Severe changes
Normal			
Mild otoscl. changes	1	8	1
Severe otoscl. changes		2	7
Total	1	10	8

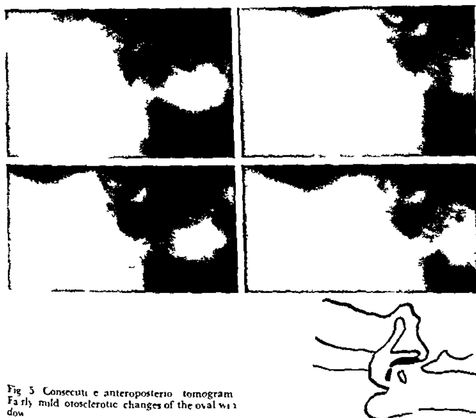


Fig 5 Consecutive anteroposterior tomogram Fairly mild otosclerotic changes of the oval window

consecutive cuts is compared with the extent of the normal window over four or five cuts The finding probably represents otosclerotic changes at the edge of the window or in the annular ligament while the base of the stapes has no otosclerotic plaques The other characteristic change was that no window could be seen in 4 to 6 tomographic cuts but instead there was compact bone without any interruption from the bony wall of the lateral semicircular canal to the upper limit of the round window (Fig 6) This was due to a bridge formation which covered the window In many of the cases there was also a thickened bony mantle corresponding to the entire inner ear

SUMMARY

Two characteristic changes narrowing of the vestibular window and a bridge formation overing the fenestra vestibuli were found in a series of patients with verified otosclerosis



Fig 6 Consecutive anteroposterior tomograms Severe otosclerotic changes of the oval window

ZUSAMMENFASSUNG

Zwei charakteristische Veranderungen die Verengung wie auch eine Bruckenbildung des vestibularen Fensters wurden in einer Serie von Patienten mit verifizierter Otosclerosis gefunden

RÉSUMÉ

Les auteurs ont trouvé sur une série de malades atteints d otosclérose vérifiée deux lésions caractéristiques un rétrécissement de la fenêtre ovale et une formation en pont couvrant la fenêtre ovale

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TOMOGRAPHY WITH THE MIMER IN OTOSCLEROSIS OF THE TEMPORAL BONE

by

BENGT LILIEQUIST

Conventional roentgenologic procedures are not suitable for the examination of anatomical details of the temporal bone involved in otosclerosis As is the case in so many other fields however the radiologic examination constitutes the only means as yet available that permits the anatomy to be assessed without surgery Therefore tomography with hypocycloid or circular motion seems to be the possible answer to the otologist when conventional methods of investigation do not permit the intricate anatomy of the middle and inner ears to be assessed In the investigation of the otosclerotic process it is of utmost importance to arrive at a correct assessment of the extent of the changes and their nature Anatomical evaluation of the result of corrective surgery in otosclerosis is likewise not possible without further operation or roentgenologic procedures

Tomographic methods in the examination of the temporal bone either linear or in the form of hypocycloid movements have been investigated by many authors ZIEDSES DES PLANTES as early as 1932 employed curvilinear tomography in a few cases Most authors have used the polytome and a vast

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Fig 1 Tomographic section posterior to the oval window showing the lateral semicircular canal and the vestibule



Fig 2 Section 1 mm anterior to the one in fig 1 The oval window appears as an opening in the bony wall of the vestibule

literature deals with the results in *normal and pathologic conditions* (BRUNNER, PETERSEN & STOFSTAD 1961, TARI 1959, FRANÇOIS & BARROIS 1959, MUNDNICH & VREY 1959, LANGEFELDT 1960, GROS et coll 1962, VALVASSORI 1963, 1965)

Tomographic examination of the temporal bone may also be performed with the Mimer, originally designed to facilitate neuroradiologic procedures, since this unit is also equipped with tomographic facilities for both linear and semicircular motion For details, reference is made to a recent work by LINDGREN & MATTSSON (1965) who have dealt thoroughly with the principle of semicircular tomography with this equipment It will be sufficient to mention that the movement is one of 180°, that a 0 6 mm focus is used, that the degree of magnification is 1 32, the time of exposure 1 sec, and that no grids are employed

Method employed The projections in tomography of the temporal bone are of considerable importance and must be selected according to the specific aim in mind The *roentgenologic investigation in otosclerosis* must be centered on the medial wall of the tympanic cavity particularly on the oval window and its surroundings and the footplate of the stapes The otosclerotic process mainly involves the bony structures of these formations and for these the conventional *projections used for examination of the middle ear* are unsuitable

The tympanic cavity is in principle a narrow slit with not quite parallel lateral and medial surfaces In the main direction the cavity forms an angle of 20°, open posteriorly in the mediosagittal plane of the skull This corresponds

mainly with the direction of the medial wall containing the anatomical details that are relevant in the otosclerotic process Projections bringing out these details have been proposed by CHAUSSE (1950) and used extensively in conventional roentgenologic examinations of the attic and antrum regions

Mainly three projections have been described in the literature for tomography of the temporal bone one a p view, a semi axial view corresponding to the Chaussé III projection, and a projection similar to the Stenvers view A lateral view has also been used for special purposes It is stated that most details of the medial wall of the tympanic cavity can be demonstrated provided one of these three projections is used

The most suitable projection and also the easiest one to repeat is a true a p view in which the temporal bone is projected through the orbit The patient lies supine, so that a line joining the tragus and the external canthus of the eye will be vertical and perpendicular to the table top According to PORTMANN & GUILLEN (1959) the attic point which virtually is a point representing the centre of the epitympanic recess is a suitable reference point for all projections of the middle ear this point in practically all adults is located 25 ± 2 mm medial to the external opening of the outer auditory canal After a little practice it is easy to direct the central beam through this point for tomography of the bone The projection may be repeated if care is taken to mark the direction of the central beam and its centre on the skin of the patient

Normal anatomy

The lateral semicircular canal as well as the vestibule and the bone delimiting these from the tympanic cavity are seen in Fig 1 The anterior semicircular canal is also partly demonstrated The tomographic cut is placed posterior to the round and oval windows and the promontory

The region of the oval window is shown in Fig 2 as a local defect in the bony wall of the vestibule The footplate of the stapes is normally several times thinner than the bony substance forming the surroundings of the oval window The latter therefore appears as a more or less distinct opening in the bony wall of the vestibule It is sometimes seen covered by a bony structure that corresponds with the footplate of the stapes the two legs of the stapes do not appear as distinct structures The inner auditory canal and the small bony septum dividing it into two compartments are also distinctly outlined The promontory lies immediately adjacent to the bony rim of the oval window (Fig 3) The lumen of the basal turn of the cochlea continuous with the lumen of the vestibule is demonstrated and the oval window is still evident as an



Fig. 3



Fig. 4



Fig. 5

Fig. 3. Adjacent to the oval window is the basal turn of the cochlea continuous with the vestibule.

Fig. 4. More anteriorly the bony spur of the posterosuperior border of the external auditory canal delimits the tympanic cavity. The round window appears as an opening in the basal turn of the cochlea.

Fig. 5. The bony ossicles are projected free from the lateral semicircular canal. The rest of the cochlea but not the basal turn is evident.

opening. Just below the lumen of the horizontal semicircular canal another small round hole containing the facial nerve is present.

The bony spur comprising the posterosuperior border of the external auditory canal and forming the lateral wall of the attic and aditus ad antrum is evident in Fig. 4. The caput of the incus and malleus are seen projected in the attic cavity on top of each other and of the horizontal semicircular canal. The round window, which is not covered by any bony lamella, appears as a small opening in the wall of the basal turn of the cochlea adjacent to the oval window. At this level the bony spur of the canal itself is apparent, as is also the greater part of the promontory.



Fig 6 Otosclerosis before and after surgery ad modum SCHUKNECHT A metal strut passes through the tympanic cavity from the oval window to the long process of the incus

The bony ossicles are free from over projection of the horizontal semicircular canal in Fig 5 but are still projected on top of each other The anterior part of the cochlea is outlined but not the part that turns basally

Pathologic changes

The pathologic changes in otosclerosis mainly involve the bony structures in and adjacent to the oval window The otosclerotic process when involving the footplate of the stapes causes its fixation to the rim of the oval window If the process attacks the stapes more extensively the footplate will be thickened sometimes to such a degree that it will assume the same thickness as the surrounding bony walls these changes can be demonstrated in roentgen films (e g VALVASSORI)

Tomography of the temporal bone may also be applied to a study of the result of surgery for otosclerosis (VALVASSORI and LANGFELDT) Various operations have been designed to correct the fixation of the stapes According to SCHUKNECHT (1960) the stapes is removed a prosthesis consisting of a fat pad is placed in the oval window and connected to the long process of the incus with a silver wire The wire measures 0 12 mm in diameter and is about 5 mm long with a hook in its lateral part around the incus and a knot medially around the fat pad The position of this metal strut in the tympanic cavity indicates its relationship to the oval window and the long process of the incus In Fig 6 the metal strut has been inserted between the oval window and the long process of the incus The lateral hook and the medial knot are not well shown The strut can always be identified provided the interval between each single section is 1 mm

SUMMARY

Tomography of the temporal bone may with advantage be performed with the Mimer All essential anatomic details of the inner wall of the tympanic cavity may be examined and the results of corrective surgery including the position of the metal strut after stapedectomy, may be demonstrated

ZUSAMMENFASSUNG

Die Tomographie des Felsenbeines kann vorzugsweise mit dem Mimer vorgenommen werden Alle wichtigen anatomischen Einzelheiten der inneren Wand der Trommelhohle und die Resultate chirurgischer Eingriffe einschliesslich der Lage eines Metallstreifens nach Entfernung des Steigbugels konnen demonstriert werden

RÉSUMÉ

Le Mimer peut être employé avantageusement pour la tomographie de l os temporal Il permet d examiner tous les détails anatomiques essentiels de la paroi interne de la caisse du tympan et d étudier les résultats de la chirurgie correctrice y compris la position de la prothèse métallique après stapédectomie

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ZIEDSES DES PLANTES B G A new method of differentiation in roentgenography (planigraphy) Acta radiol *13 (1932) 182*

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WIDTH OF THIRD VENTRICLE

Encephalographic and morbid anatomical study

by

ARNE BORGERSEN

Measurement of the width of the third ventricle takes a part in routine encephalography especially in the evaluation of cerebral atrophy The literature contains several references to the width of the third ventricle measured in encephalograms and in casts of the cerebral ventricles Most authors have measured the width of the anterior part of the ventricle in anteroposterior roentgenograms obtained with the brow up and air in the foremost part Some of the results obtained by various authors are recorded in Table I

Considerable variation in the various materials is apparent This may be due e g to the varying influence of disease varying age and sex composition and different techniques Thus ABRAMOWITSCH & WINKLER (1930) in presenting the first measurements of the ventricular system used a focus film distance of only 55 cm Their patients were mostly young with ages ranging from 2 to 53 years Most of HEIDRICH s (1955) patients were also not over 50 years There was furthermore a great male preponderance (152 males and 18

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SUMMARY

Tomography of the temporal bone may with advantage be performed with the Mimer. All essential anatomic details of the inner wall of the tympanic cavity may be examined and the results of corrective surgery, including the position of the metal strut after stapedectomy may be demonstrated.

ZUSAMMENFASSUNG

Die Tomographie des Felsenbeines kann vorzugsweise mit dem Mimer vorgenommen werden. Alle wichtigen anatomischen Einzelheiten der inneren Wand der Trommelhöhle und die Resultate chirurgischer Eingriffe, einschliesslich der Lage eines Metallstreifens nach Entfernung des Steigbügels, können demonstriert werden.

RÉSUMÉ

Le Mimer peut être employé avantageusement pour la tomographie de l'os temporal. Il permet d'examiner tous les détails anatomiques essentiels de la paroi interne de la caisse du tympan et d'étudier les résultats de la chirurgie correctrice, y compris la position de la prothèse métallique après stapédectomie.

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through the third ventricle postero anteriorly These authors in 203 successive encephalographies found an average width of the posterior part ranging from 6.24 to 11.20 mm as recorded below according to age groups

Years	(Cases)	Average width in mm
6—15	(25)	6.24
16 to 25	(31)	7.00
26 to 35	(38)	7.60
36 to 45	(44)	8.60
46 to 55	(32)	9.24
56 to 65	(24)	11.20
66 to 75	(9)	10.88

It appears from these data that the width generally increases with age the average width in the material was 8.68 and in 31 patients it exceeded 12 mm (A Lysholm skull table and a focus film distance of 90 cm were used in ENGESET & LØNNUM s material) Many pathologic conditions were also includ ed but a definite tendency towards higher values than those given above was evident

NELSON et coll (1964) have recently adopted Engeset s technique except that they used a focus film distance of 100 cm in the examination of 30 patients with disorders of movement and in 40 patients with other neurologic abnor malities A 10 % magnification error was subtracted from each value The average posterior width of the third ventricle was 9.2 mm in the disorder of movement group and 6.7 mm in the control group

The only systematic measurements apparently of the width of the third ventricle in a series of casts from the human brain have been carried out by LAST & TOMPSETT (1953) They made casts from 24 apparently normal adult brains and reported a maximum average width of 5.5 mm (min 4 max 11 mm) This is considerably lower than in many encephalographic materials although the part of the ventricle from which the measurements were taken was not stated

The question of whether the ventricles increase in size with age has been much debated HEINRICH (1939) examined 100 encephalograms from pre sumably normal patients by means of planimetry and found an increase in the surface area of the ventricles directly proportional to age A gradual increase in size started after the 10th year and became more marked after the patient was 60 to 65 years old This applied both to the lateral and third ventricles No increase in volume with age occurred in LAST & TOMPSETT s (1953) series of 24 casts

KNUDSEN (1958) on the other hand reported a statistically significant increase in the average volume of the lateral ventricles in patients over 50

Table 1

Previous measurements of third ventricles with air in its anterior part

Authors	Material	Method	Width in mm
ABRAMOWITSCH & WINKLER 1930	60 imbeciles, psychotics, epileptics	Stereoscopic FFD 35 cm	4.1 to 6.8
Davidoff & Dyke (editors) 1946	Not stated	Not stated	*2 to 8*
ORLEY (editor) 1949	Not stated	Not stated	2 to 8
SCHIERSMANN (editor) 1952	Not stated	Not stated	5
HEIDRICH 1953	139 cases of traumatic hydrocephalus	Planimetry FFD 90 cm	2 to 18 (aver. 7.6)
NÜRNBERGER & SCHALTENBRAND 1955	32 normal encephalograms	Orthoroentgenography FFD 90 cm	3 to 6
ROBERTSON (editor) 1957	Not stated	Not stated	3 to 9
BRUIJN 1959	163 cases of cerebral atrophy	FFD 100 cm, 8 cm OFD	Aver. 8.2
PELTONEN 1962	644 neuropsychiatric patients	FFD 70 cm	2 to 15 (two thirds between 5 and 8)

females). NÜRNBERGER & SCHALTENBRAND (1955) had a rather small material of third ventricles but their technique was excellent. BRUIJN (1959) selected 163 patients with the clinical diagnosis of 'cerebral atrophy'. He used a focus film distance of 100 cm but when employing a Bucky diaphragm obtained a skull film distance of 8 cm. PELTONEN (1962) had a large material of neuropsychiatric patients but the widths he measured, at a focus film distance of only 70 cm, were somewhat larger than in most materials. Some textbook authors, without giving measurements of the two parts of the third ventricle, describe the posterior part as being wider or having a more rounded shape than the anterior part (DAVIDOFF & DYKE 1946, ROBERTSON 1957, SCHIERSMANN 1952).

INGESET & LONNUM (1958) were the first to confine the measurements to the posterior part of the third ventricle. They obtained air filling of the posterior part by tilting the head slightly forwards, with the patient in sitting position, the roentgen beam being directed at various angles to the horizontal plane

ENGESET & LØNNUM suggest that the width of the posterior part may be greater There seems to be no general agreement as to the normal width of the third ventricle nor of the variation with age and sex

The present investigation was divided into two sections The first section represented an analysis of the anterior and posterior widths of the third ventricle in 100 consecutive encephalograms The second section was based on measurements of casts of the third ventricle from 100 brains obtained at autopsy The purpose of the investigation was to determine whether (1) the normal width of the third ventricle may be defined more exactly (2) if a real difference in width between the anterior and posterior parts of the third ventricle exists and (3) whether the width of the third ventricle varies with age and sex in the same way as the lateral ventricles and if so whether there is a difference between the anterior and posterior parts

1 Encephalographic investigations

Material and Methods One hundred consecutive encephalograms from 62 men and 38 women were examined with a modified Robertson technique on a Lysholm skull table at a FFD of 90 cm 30 ml of air being injected by the lumbar route Postero anterior films were obtained with the patient sitting upright the head being inclined in various planes to the central beam and with air in the posterior part of the third ventricle The patient was then placed in supine position and anteroposterior films were obtained with the brow up and air filling the anterior part of the ventricle The width of the third ventricle in its posterior and anterior parts was measured the measurements of the latter were obtained superiorly just below the foramen of Monro (see Fig 1) Since the mid point of the third ventricle in the lateral view is situated at approximately equal distances from the brow and the occiput the possibility of getting a different magnification of the two parts in the frontal films may for practical purposes be ruled out

Results The numbers of encephalograms from a total of 100 in which the width of the anterior and posterior parts of the third ventricle could be measured are indicated below

Measurable in both anterior and posterior parts (36 men and 22 women)	58
Measurable only in posterior part	35
Measurable only in anterior part	4
Not measurable	3



Fig. 1. a) Postero-anterior encephalogram with air in posterior part of third ventricle; the arrows indicate points of measurement. b) Anteroposterior encephalogram (brow up) with air in anterior part of third ventricle; the points of measurement are at the anterior part of sulcus hypothalamicus (arrows).

years of age, although a third of the 70- and 80-year age groups had the same volume as 90% of the 20-, 30-, and 40-year age groups. The material consisted of 183 normal adult brains, the third ventricle not being examined for age and sex variance. BRUIJN (1959) divided his 163 patients into those below and those over 20 years of age, and although the tendency pointed to an increase in ventricular size with age, this could not be statistically confirmed. Sex difference in size of the lateral ventricles has been reported in the materials of KNUDSEN and LAST & TOMPSETT. The average volume of the lateral ventricle in KNUDSEN's series was 7.27 ml in the male and 6.76 in the female. LAST & TOMPSETT described a greater minimum thickness of the lateral ventricles in men than in women, both on the left and the right sides. The third ventricle, however, was not affected by sex. BRUIJN's 163 patients consisted of 102 males and 61 females, the average width of the anterior part of the third ventricle being 8.8 mm in the male and 7.2 in the female. PELTONEN (1962) reported a relatively small effect of age upon the width of the third ventricle but a little greater width in males than in females. NELSON et coll. (1964) likewise described a greater width in males in both groups, but only in the males in the disorder of movement group was a significant correlation found between ventricle size and age.

The literature thus indicates that most authors have measured the width of the anterior part of the third ventricle. Some observations, especially those of

The measurements thus suggest that there is a definite tendency towards a greater width for the posterior part of the third ventricle The difference is however not great and generally amounts only to 1 to 2 mm Furthermore it is striking that the posterior part is the much easier to measure as has been pointed out by ENGESET (1964) Thus accurate measurement of the anterior part was not possible in 38 patients whereas the posterior part could be measured in 93 of the 100 patients The width of the posterior part increases with age and in both parts the width is slightly greater in men than in women

As the series by no means constitutes a normal material no conclusion can be drawn as to the normal width of the third ventricle The age group 6 to 15 years in particular comprises many pathologic conditions that account for the high values in this group Among these were two brain stem tumors

II Morbid anatomy investigations

Material and Methods The material consists of 100 brains All brains with gross focal lesions were excluded, otherwise the brains were taken successively regardless of age sex and clinical and pathologic diagnoses The material thus includes a few brains that on section had minor pathologic changes (old infarctions small internal hemorrhages) These are incorporated in a pathologic material of 27 brains from patients with diagnosed neurologic and psychiatric diseases mental deterioration and chronic cerebrovascular disease The remaining 73 brains were considered essentially normal on macroscopic and/or microscopic examination the clinical examinations also having revealed no symptoms or signs of neuropsychiatric disease These 73 brains represent the normal material The main causes of death were malignant tumors and coronary heart disease

The brains after removal from the skull were weighed and inspected and the basal vessels either removed or opened The brains were then immersed in a 10 % formalin solution (formalin 40 % and water 1 3) and suspended by a thin cord in the interhemispheric fissure After fixation for about 14 days the brains were immersed in water for one day

The casts of the third ventricle was made from Silopren paste K I (Bayer) This rather viscous fluid can be injected with a syringe and consists of a silicon rubber mixture that hardens at room temperature after the addition of a cross linking agent Silopren Vernetzer KA

The following procedure was used a suitable amount of Silopren K I was carefully mixed with 1 % of the agent KA (0 1 ml agent to 10 ml Silopren) and the mixture poured into a 10 ml syringe The brain stem was cut at the level of the peduncles and a small opening of drainage made in the bottom

Table 2

Widths of anterior and posterior parts of the third ventricle (in mm) measured in 58 encephalograms (36 men and 22 women)

	Minimum	Maximum	Average	Average in men	Average in women
Width of anterior part	2	12	7.2	7.9	6.2
Width of posterior part	4	15	8.4	9.0	7.4
Difference			1.2	1.1	1.2

As is evident from these data, the width of both parts could be measured only in 36 men and 22 women. The measurements from these 58 patients are given in Table 2 and the differences in width between the posterior and anterior parts of the third ventricle in these patients are tabulated below.

No difference in		15
Wider in posterior part		
	1 mm in	22
	2 mm in	15
	3 mm in	1
	4 mm in	1
	5 mm in	1
	6 mm in	1
Wider in anterior part	1 mm in	2

The average width of the posterior part was 1.2 mm greater than that of the anterior part but no difference between the two parts existed in 15 of the patients. Only 2 patients had a greater width in the anterior part, whereas in the remaining 41 patients the width was greater in the posterior part.

The width of the posterior part of the third ventricle in our material could be measured in 93 patients. These have been arranged in the same age groups as ENGESET & LONNUM's material in order to compare the findings. The two materials revealed the same general increase in ventricular size with age, as may be seen from the data given below, ENGESET & LONNUM's values being given in brackets.

Age groups	(Cases)	Average width of posterior part of 3rd ventricle
6 to 15 years	(7)	9.14 (6.24) mm
16 to 25	(17)	7.59 (7.00)
26 to 35	(15)	8.26 (7.60)
36 to 45	(24)	9.29 (8.60)
46 to 55	(9)	7.00 (9.24)
56 to 65	(18)	9.88 (11.20)
66 to 75	(3)	10.33 (10.88)
	Average	8.77 (8.68)

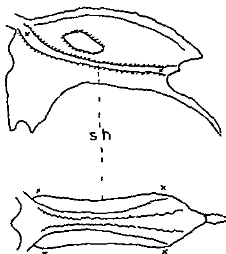


Fig 4 Third ventricle shown schematically with the points of measurement marked with an × (s h stands for sulcus hypothalamicus)

just beneath the foramen of Monro and ending at the posterior commisure The foremost part of the sulcus has a small outward bulge which can be clearly seen in Fig 3 at which the measurement of the anterior width was taken A caliper with an accuracy down to 0 1 mm was used for the measurements Fig 4 indicates the exact points of mensuration

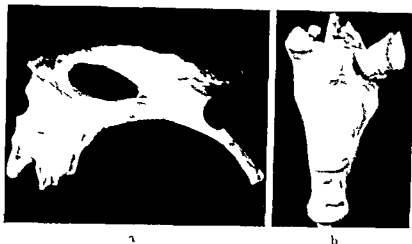
Results The 100 casts represent an unselected random material and will first be considered as a whole No difference between the anterior and posterior parts existed in 7 of the casts but the posterior part was wider in 60 and the anterior part was wider in 33 cases As is evident from Table 3, the average width of the third ventricle was a little less than 7 mm

The average difference between the posterior and anterior parts amounted to about 0 2 mm a very small value The variations in width difference

Table 3

Width of 3 d ventricle in mm

	Minimum	Maximum	Average		
			100 casts	73 normal casts	27 pathologic casts
Width of anterior part	1 4	13 9	6 73	6 41	7 71
Width of posterior part	2 8	14 4	6 90	6 71	7 59



a b

Fig 2 Casts of third ventricle in lateral (a) and frontal (b) views



Fig 3 Coronal view of cast of third ventricle The irregular lines in the roof are caused by the choroid plexus

of the third ventricle at the infundibular recess The tip of the syringe, without a needle was then inserted into the aqueduct, and the thick fluid slowly injected until an ample amount emerged from the slit in the recess The brain was then put back into water After about 24 hours the cast was removed in the following way a careful incision was made in the midline of the base until the floor of the third ventricle was opened When excess material had been cut off at the foramen of Monro, the complete cast was lifted out from its site, briefly dried in the air and the measurements performed Lateral and frontal as well as coronal views of typical casts are shown in Figs 2 and 3

The cast was often incomplete and to obtain 100 complete casts about 300 brains had to be injected

The anterior and posterior parts of the sulcus hypothalamicus were chosen as reference points for measurement of the width of the third ventricle, these points corresponding to those measured in the encephalograms The sulcus hypothalamicus is easily seen in the cast as a ridge along its side, beginning

Table 4

Comparison between casts greater and less than 7 mm in width in a total of 100 casts

Greatest width of casts	Number of casts	Casts equally wide in ant and post parts	Casts wider in anterior part	Casts wider in posterior part	Aver width in ant part	Aver width in post part
< 7 mm	43	5	8	30	4 7	5 1
> 7 mm	57	2	[illegible]	[illegible]	8 6	8 5

The tendency for the width to be greater in the posterior part was investigated by comparing each pair of measurements and testing the differences between the anterior and posterior parts with the Wilcoxon matched pair signed rank test (SIEGEL 1956) As a result of this two-tailed test for all 100 casts a P value of 0 0562 was obtained This is close to the conventional level of significance which is < 0 05 When however the 73 normal casts were tested the P value was 0 009 In other words a statistically significant tendency towards greater width of the posterior part of the third ventricle was evident in the normal brains

The average width of the third ventricle in the whole material was a little less than 7 mm (see Table 3) According to this the material was divided into casts with greatest width below or up to 7 mm and casts with greatest width exceeding 7 mm The results are given in Table 4 There was an almost equal number of casts in each group In the group below or up to 7 mm the great majority of the ventricles were wider in the posterior part this difference being highly significant according to the Wilcoxon test (P = 0 00014) In the group wider than 7 mm nearly half the number of ventricles were wider in the anterior part and the average width was a little greater in the anterior part a tendency however not statistically significant (P = 0 69)

The group of ventricles from patients with clinically diagnosed neuropsychiatric disease was heterogenous and comprised 10 with psychoses 8 with cerebro vascular disease 3 with epilepsies 2 with dementia one with cerebral tumor one with cranial trauma one with general palsy (and sequelae) and one with non ascended spinal cord 27 patients in all The greatest variations were found in this group with the anterior width ranging from 2 7 to 13 9 mm and the posterior width from 2 8 to 14 9 mm The average width was greater than in the whole material as shown in Table 3 and more obvious in the anterior than in the posterior part The Wilcoxon test failed to show any significant preponderance of the anterior part (P = 0 6)

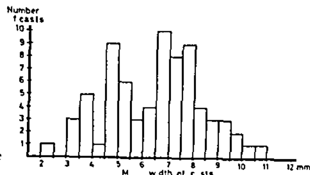


Fig. 5. Distribution of mean widths in the 73 normal casts

between the posterior and anterior parts of the third ventricle in the total of 100 casts are recorded below

		Number of casts
No difference in		7
Wider in posterior part		
	0 1—0 5 mm in	24
	0 6—1 0 mm in	17
	1 1—1 5 mm in	13
	1 6—2 0 mm in	1
	2 1—2 5 mm in	3
	2 6—3 0 mm in	2
		60
Wider in anterior part		
	0 1—0 5 mm in	10
	0 6—1 0 mm in	7
	1 1—1 5 mm in	7
	1 6—2 0 mm in	4
	2 1—2 5 mm in	3
	2 6—3 0 mm in	2
		33

The difference between the two parts was usually less than 1 5 mm The greatest difference measured in both groups was 3 mm (as compared with 6 mm in the encephalograms)

The difference between the anterior and posterior parts being in fact rather small, it was considered of interest to investigate the mean width of the 73 'normal' casts This was found to be 6 50 mm, ranging from 2 10 to 10 55 mm These casts were arranged in groups with up to 0 5 mm width difference between each group (Fig 5) Fifty three casts, or 72 6 % had a mean width between 4 5 and 8 5 mm and 10 casts had a mean width above 8 5 mm The last mentioned 10 casts represented nine men and one woman of an average age of 67 3, as compared with 60 4 years for the total of 73 casts

however the sex distribution within the age groups of Table 5 was examined in all groups except the 36 to-45 year group the width was greater in the male ventricles both in the anterior and posterior parts The figures within each group of course were small and hardly allow definite conclusions to be drawn

Discussion

The present investigations have indicated that

1 The average mean width of the normal third ventricle as measured in casts was 6 5 mm (6 4 mm in the anterior and 6 7 mm in the posterior part) Approximately three quarters of 73 normal casts had a mean width between 4 5 and 8 5 mm ranging between 2 10 and 10 55 mm

2 The posterior part was a little wider than the anterior part in small third ventricles but the difference tended to be reversed with increasing s ze of the ventricle With a conventional technique the posterior width of the third ventricle was easier to measure in encephalograms than the anterior width

3 The width of the third ventricle increased with age and was greater in men than in women

The possible errors of the methods, and subsequently the implications of the results attained will now be discussed

The methods A standard and meticulous technique is essential for measurements in encephalograms As pointed out by HEIDRICH (1955), even small deviations of the patient s head may produce differences of up to 2 mm in width of the third ventricle This may be in favour of the technique advocated by ENGESET (1964) which gives more projections in which to measure the air both in the posterior and anterior parts Other factors that favour measurement of the posterior part are the following poor air filling of the anterior part may ensue if too much air escapes into enlarged lateral ventricles furthermore the third ventricle is often obscured in anteroposterior films by septa of the frontal sinuses The question of a possible (and not disproved) distension of the ventricles by the air (GUTTMANN 1936 p 230) have made many roentgenologists sceptic as to the value of mensuration This difficulty may to some extent be overcome by using the same amount of air and taking the films as soon as possible after insufflation (LINDGREN 1951)

Some remarks must be made about the magnification of the third ventricle in films With a focus film distance of 90 cm and a fine focus tube the magnification of a third ventricle with an actual width of 7 mm amounts to about 1 mm i e the width measured in the encephalogram would be 8 mm (if the skull had a longitudinal diameter of 20 cm) According to this the average width of

Table 5

Width of 3rd ventricle in 69 casts of different age groups

Age groups years	Number of casts	Average width		Average mean width	Average brain weight
		ant. part	post. part		
36 to 45	7	4.9	5.2	5.05	1430
46 to 55	9	5.4	5.8	5.6	1490
56 to 65	26	6.3	6.6	6.45	1410
66 to 75	27	7.1	7.3	7.20	1380

These findings indicate that the normal third ventricle, especially when narrower than 7 mm, has a statistically significant tendency towards a greater width for the posterior part. On the other hand, ventricles wider than 7 mm, including most of the 'pathologic' ventricles, seem to tend towards a greater width for the anterior part, even though this could not be statistically confirmed.

Variation with age. The 73 'normal' casts were divided into different age groups, 69 of these being placed in the age groups 36 to 75 years. Table 5 reveals an increasing average width with age. Regression analysis showed that *this increase was significant at the 1 % level for both the anterior and* posterior parts. However, the difference between the anterior and posterior parts did not change significantly with age.

Variation with sex. Of the 73 'normal' casts, 48 were from male and 25 from female brains. Table 6 reveals an average difference in width of about 2 mm between the male and the female casts, both in the anterior and posterior parts. On the average, the posterior part of the third ventricle was 0.2 mm wider than the anterior part in the male, as opposed to 0.4 mm in the female. The average age of the women was nearly 4 years less than that of the men. When,

Table 6

Width of 3rd ventricle in 73 casts from males and females

Sex	Number of casts	Average width		Average mean width	Average brain weight	Average age
		ant. part	*post. part*			
Male	48	7.0	7.2	7.1	1460	61.43
Female	25	5.1	5.5	5.3	1320	57.68

towards a swelling of the brain during fixation This would mean a corresponding diminution in the size of the ventricles KNUDSEN on mostly theoretical grounds held that this diminution is rather small, but exact information on the point is lacking

The present author examined 10 brains radiologically post mortem before and after fixation in an attempt to obtain more information on this problem The transverse diameter of the frontal horns was compared and the average transverse linear shrinkage was found to be 1 6 mm or 3 4 % This would correspond to a transverse shrinkage of less than 0 3 mm of a third ventricle of 8 mm width measured on the encephalogram and may be considered negligible A detailed description of the method employed in this investigation will appear in a later article

A further question to be considered is the possibility of distending the ventricle during injection of the Silopren paste Because of the viscosity of the material the injection was very slow and the pressure inside the third ventricle correspondingly low Moreover a slit was made in the floor of the third ventricle which allowed the escape of fluid when the ventricle was filled

The qualities of Silipren will be discussed in a subsequent paper Suffice it in this connection to state that the method is well suited for examination of limited parts of the ventricular system It seems easier to handle than the plastics otherwise used (TOMPSETT 1956 ECKERBOM 1959 WESTBERG 1963) and can be removed without seriously impairing the subsequent pathologic examination of the brain The shrinkage of the Silopren casts during hardening amounts to only 0 5 % when 1 % crosslinking agent is used (HELMETH 1961) Silopren has hitherto been used chiefly in museum technique (HELMETH) and in dentistry (LARBY 1961)

Implications of the findings The establishment of normal values of ventricular size is questionable The main difficulty lies in obtaining a reliable normal material No conclusions as to normal measurements can be drawn from the encephalographic part of this work since all the subjects examined had or probably had neuro psychiatric disease The 73 normal casts on the other hand may not represent a true normal material in the strictest sense but seem to come as close to it as can reasonably be expected Since the patients had not been examined with a special view to the problem in question minor neurologic and psychiatric disturbancies may have passed undetected

According to the present work the average normal width of the third ventricle is close to 6 5 mm or less than 8 mm in encephalograms More important than the average width however may be the upper normal limit and this cannot be definitely established What can be said from the present work is

the third ventricle casts in this material would be about 8 *mm if measured* in encephalograms Conversely, the true average widths of the third ventricle encephalograms in this material would be 6 4 mm in the anterior part and about 7 5 mm in the posterior part The latter width corresponds well with the posterior width of the pathologic casts (Table 3), but the former may suggest that the air filling of the anterior part of some ventricles may have been inadequate, possibly not extending behind the foramen of Monro This would explain the greater difference between posterior and anterior measurements in the encephalograms as compared with the casts

As regards *measurements in encephalograms, some confusion concerning* the results obtained by various authors using different techniques might be avoided if all measurements were reduced to true dimensions (NELSON et coll 1964)

A conventional roentgen technique has been used in the present study Tomography would probably have enabled the anterior part of the third ventricle to have been measured in a greater percentage of patients It would certainly be the method of choice if further investigations in this field were to be undertaken

The mensuration of ventricular dimensions in the brain itself, even when sufficiently hardened, is of limited value due to inevitable distorsion of the ventricles The indirect study of the ventricular system by means of casts is therefore indispensable

A common finding on pathologic examination is that the ventricles generally appear smaller in sections of the brain than they do in premortal encephalograms BONING (1925) and others have shown that a swelling of the brain together with a reduction of the amount of cerebrospinal fluid takes place post mortem It is not known how much this swelling affects the cerebral ventricles

The fixation of the brain in formalin is another factor that may influence the size of the ventricles KNUDSEN advocated fixation in 1 % formalin to which was added 1 75 % NaCl, as this solution gave an increase in the weight and volume of the brain of only 0 5 % This swelling was less than with other fixatives LAST & TOMPSETT used 10 % formalin and reported an average linear shrinkage well under 2 % in 10 brains On the other hand, TREFF & KRAUS (1960), with a fixation *period of 20 days with 4 % formalin, reported* a weight increase of 7 % and a volume increase of 14 %, with 10 % formalin a weight increase of 3 % and a volume increase of 5 %, and with 10 % formalin a weight decrease of 7 % and a volume decrease of 6 % The number of brains investigated in their work was not stated Different results have thus been obtained by different investigators but most observations seem to point

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that most normal ventricles have a width of between 4.5 and 8.5 mm, or between 5 and 10 mm in encephalograms. Widths above 10 mm may not necessarily be pathologic but should be suggestive and call for a thorough neuropsychiatric examination. Judgment in a given subject must rest also on age, sex, site of measurement and the relation to other parts of the ventricular system and skull breadth. Most authors who have studied the lateral ventricles agree upon their marked normal variations. As has been shown, this holds true also for the third ventricle.

The tendency towards relatively greater width of the posterior part in small third ventricles seems well established from the present findings. However, the difference is not great and tends to be reversed in large ventricles.

There is a clear tendency for the third ventricle to increase in width with age, and in general it is wider in men than in women. The third ventricle thus follows the same pattern as has been demonstrated for the lateral ventricles (HEINRICH 1939, LAST & TOMPSETT 1953, KNUDSEN 1958).

SUMMARY

The anterior and posterior widths of the third ventricle were examined in 100 encephalograms and 100 casts. The average anterior width was 7.2 mm and the posterior width was 8.4 mm in encephalograms, the average widths being 6.4 and 6.7 mm respectively in 73 casts from clinically normal patients. The widths increased with age and were greater in men than women.

ZUSAMMENFASSUNG

Der vordere und hintere Durchmesser des dritten Ventrikels wurde an hundert Enzephalogrammen und 100 Ausgussen bestimmt. Der vordere Durchmesser betrug durchschnittlich 7.2 mm und der hintere durchschnittlich 8.4 mm in den Enzephalogrammen, bei den Ausgussen von 73 klinisch normalen Gehirnen betrugen die Werte je 6.4 und 6.7 mm. Die Werte stiegen mit dem Alter an und sie waren höher bei Mannern als bei Frauen.

RÉSUMÉ

L'auteur a mesuré sur 100 encéphalographies et sur 100 moulages la largeur du troisième ventricule dans ses parties antérieure et postérieure. La largeur antérieure moyenne était 7,2 mm et la largeur postérieure était 8.4 mm sur les encéphalographies mais respectivement 6.4 mm et 6.7 mm en moyenne sur 73 moulages de sujets cliniquement normaux. Ces largeurs augmentent avec l'âge et sont plus grandes chez les hommes que chez les femmes.

needle is probably less when it is directed towards the rather firm musculature of the left ventricle than for instance when it is pointed towards the muscula ture of the atrium

The needle is introduced with its bevelled surface lying tangentially to the cardiac wall Contact with the pericardium being established the needle is only slightly pushed further forwards After attempted aspiration with the syringe with no blood appearing a small amount of contrast medium is injected and its passage is observed on the monitor screen With the needle retained in the same position, the syringe is detached from the needle and a thin flexible steel wire with a soft tip is introduced through the needle to the pericardium the needle is then removed leaving the mandrin in the pericardium A polythene catheter with an external diameter of 3 mm is introduced into the pericardial space with the help of the steel wire The latter is thereafter removed and the position of the catheter is controlled by injection of a small amount of contrast medium

The catheter in one of the experiments in animals was left in position in the pericardial sac for 3 weeks and in another experiment for 14 days Autopsy revealed no markedly increased amount of fluid in the pericardium in either of these experiments On the other hand there was a streak with a ragged uneven outline on the pericardial and epicardial surfaces at the site of the catheters other parts of the surfaces were without macroscopically obvious changes

Catheterization of the pericardium in man Blood alone or blood and contrast medium were sucked out after the percutaneous introduction of a catheter into the pericardial cavity in four cases The catheterization was in principle performed in the same way as in the preliminary experiments in dogs Local instead of general anesthesia was used however

The technique for the catheterization of the pericardium in man is illustrated in Fig 1 Local anesthesia just to the right of the xiphoid process follows careful sterilization of the skin The soft tissues towards the pericardium are also anesthetized which means that a needle about 15 cm in length has to be used The anesthetizing needle is introduced parallel to the median plane at an angel of about 45 to the horizontal plane It is then withdrawn and a small incision is made in the skin at the injection site a puncture cannula with an outer diameter of 1 7 mm and an inner diameter of 1 mm is then insert ed in the same direction as the needle The cannula is coupled during the puncture to a 20 ml syringe half filled with Urografin 60 % The introduction of the cannula should be performed with the help of image intensifier roentgen television After the region of the wall of the left ventricle is reached the cannula

FROM THE DEPARTMENT OF THORACIC RADIOLOGY (DIRECTOR BJORN NORDENSTROM), KAROLINSKA SJUKHUSET, STOCKHOLM, SWEDEN

PERCUTANEOUS CATHETERIZATION OF THE PERICARDIUM

by

BJORN NORDENSTROM

Pathologically increased amounts of fluid in the pericardium can be removed after the introduction of a sharp needle into the pericardial cavity. This procedure has been adopted in connection with the occurrence of transudate, exudate or hemorrhage in the pericardium threatening to bring about cardiac tamponade. The possibilities of introducing a catheter into the pericardium have been tried and seem to imply certain advantages compared to the conventional technique with a needle.

Preliminary experiments in dogs. A roentgen opaque polythene catheter was introduced into the pericardium in the following way in 5 dogs examined under nembutal narcosis. A sharp puncture cannula, 12 cm in length and with an inner diameter of 1.0 mm, was attached to a 20 ml glass syringe half filled with 10 ml Urografin 60 %. A 4 to 5 cm long incision was made in the skin, suitably prepared, immediately to the right of the xiphoid process, with the animal supine. The puncture needle was then intoduced through the incision under fluoroscopy (image intensifier) control and advanced against the wall of the left ventricle. The risk of perforation of the heart wall with the

Submitted for publication 28 April 1965

needle is probably less when it is directed towards the rather firm musculature of the left ventricle than for instance when it is pointed towards the musculature of the atrium

The needle is introduced with its bevelled surface lying tangentially to the cardiac wall Contact with the pericardium being established, the needle is only slightly pushed further forwards After attempted aspiration with the syringe with no blood appearing a small amount of contrast medium is injected and its passage is observed on the monitor screen With the needle retained in the same position the syringe is detached from the needle and a thin flexible steel wire with a soft tip is introduced through the needle to the pericardium the needle is then removed leaving the mandrin in the pericardium A polythene catheter with an external diameter of 3 mm is introduced into the pericardial space with the help of the steel wire The latter is thereafter removed and the position of the catheter is controlled by injection of a small amount of contrast medium

The catheter in one of the experiments in animals was left in position in the pericardial sac for 3 weeks and in another experiment for 14 days Autopsy revealed no markedly increased amount of fluid in the pericardium in either of these experiments On the other hand there was a streak with a ragged uneven outline on the pericardial and epicardial surfaces at the site of the catheters other parts of the surfaces were without macroscopically obvious changes

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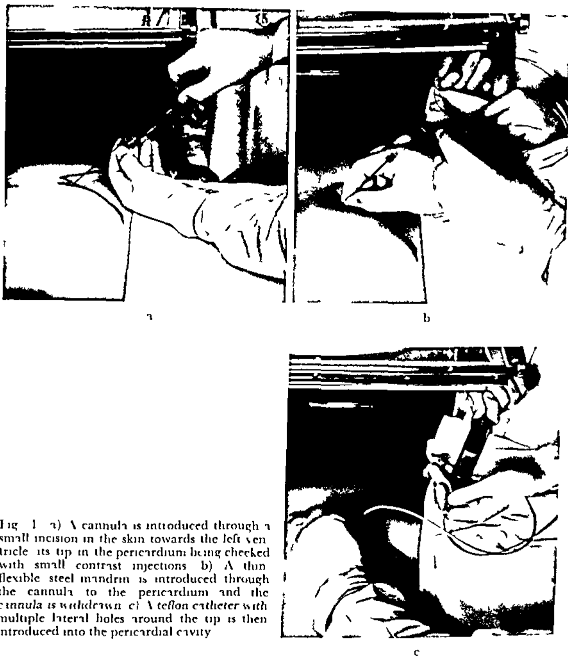


Fig. 1. a) A cannula is introduced through a small incision in the skin towards the left ventricle, its tip in the pericardium being checked with small contrast injections. b) A thin flexible steel mandrin is introduced through the cannula to the pericardium and the *cannula is withdrawn. c) A teflon catheter with* multiple lateral holes around the tip is then introduced into the pericardial cavity.

is pushed only slightly forwards. If in this position blood can be aspired, and the cannula should happen to be in the right atrium or ventricle, this can easily be checked by injection of contrast medium, which will quickly disappear. If the tip of the cannula is positioned in the pericardial sac, the medium will be seen to pass into the latter. If the cannula should be in any of the heart cavities, it should be carefully withdrawn while injecting minimal amounts of

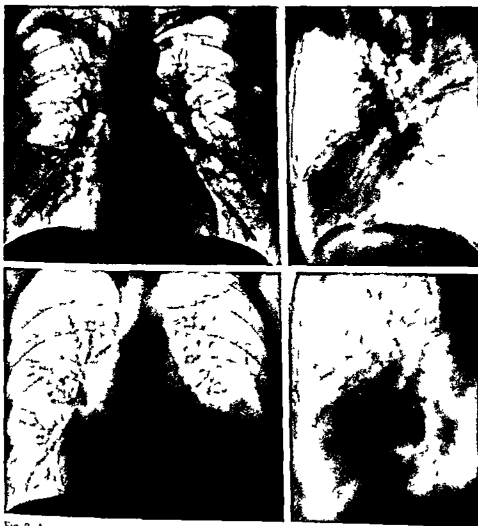


Fig 2 Appearances of the heart in a 25 year-old man with mitral stenosis before commissurotomy (upper views) and some days after the operation (lower views) when clinical signs of cardiac tamponade had developed

contrast medium until the point of the needle has reached the pericardial cavity With the mandrin correctly positioned in the pericardial cavity it can be moved about relatively freely on the surface of the heart and observed on the monitor screen The cannula is then withdrawn and with the help of the mandrin a roentgen-opaque teflon cather with a narrow hole in the tip and multiple lateral holes is inserted The mandrin is withdrawn when the catheter

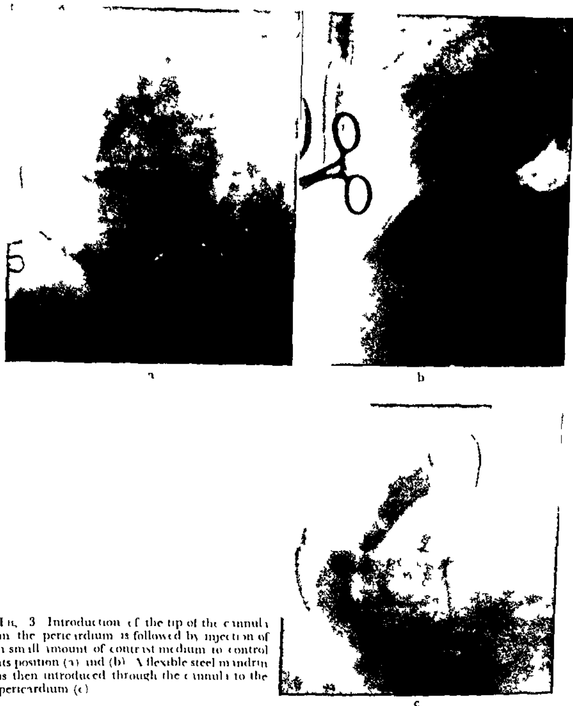


Fig. 3 Introduction of the tip of the cannula in the pericardium is followed by injection of a small amount of contrast medium to control its position (a) and (b) A flexible steel mandrin is then introduced through the cannula to the pericardium (c)

has passed into the pericardial cavity, after which the position of the latter is controlled by the injection of a small amount of medium Any increased amount of fluid in the pericardial cavity may now be withdrawn, independently of where the tip of the catheter may happen to lie It is also possible to place

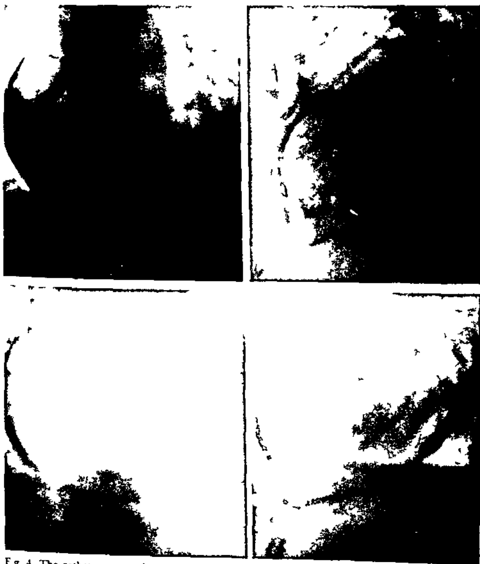


Fig 4 The catheter is introduced into the pericardium with the help of a steel mandrin (upper views) and a small amount of medium injected to check the position The heart after withdrawal of 90 ml contrast medium and blood is shown in the lower view

the patient in different positions on the examination table and this should considerably facilitate the evacuation of fluid from the pericardial sac The catheter may be left in situ for renewed suction of fluid, or for the injection of drugs for instance



Fig. 5. Contrast medium and blood in the pericardium after contrast injection via a heart catheter (During the injection the catheter recoiled from the pulmonary artery and perforated the anterior wall of the right ventricle.) a) A steel mandrin has been introduced through a cannula into the pericardial cavity followed by a teflon catheter. b) Contrast medium and blood have been withdrawn.

As far as can be judged from the experience gained in the experiments in animals, no damage to the myocardium should be caused by this procedure. No untoward reactions have been observed in these four human subjects.

In Fig. 2 (the upper views), antero posterior and lateral roentgenograms of the heart are shown, before an instrumental commisurotomy with a Dubost dilator from the left ventricle. The heart after the operation increased gradually in size, and ten days later it presented the appearances shown in the lower views of Fig. 2. The patient had clinical signs of heart tamponade. The pericardium was punctured on two occasions and blood sucked out from the latter via a puncture needle. As it was not possible to arrange any satisfactory permanent drainage of the pericardium and there were renewed signs of incipient cardiac tamponade, the pericardium was catheterized.

The needle for local anesthesia of the skin and the soft tissues has reached the pericardium in Fig. 3 a and b. It was easy to check the position of the point of the cannula on the monitor screen, both antero posterior and lateral projections being used for this purpose.

When the cannula had reached the pericardium a small amount of contrast medium was injected as previously described (Fig. 3a). The thin flexible steel mandrin was then introduced into the pericardium (Fig. 3c), and with its help a catheter with an end hole and multiple lateral holes was introduced

The position of the catheter in the pericardium after the injection of an additional small amount of medium to ascertain its correct site is shown in Fig 4 (upper views) A good 90 ml of blood and medium were then aspirated this necessitating placing the patient in both the left and right lateral positions After the aspiration of this amount of fluid there was nevertheless a small amount left around the right side of the heart (Fig 4 lower views) The thickness of the layer of contrast medium also indicated that the enlargement of the pericardium was not only caused by the increased amount of pericardial fluid dilatation of the heart was apparently also present The medium could not be moved to the left side of the pericardial cavity by positioning of the patient, due perhaps either to synechias or to blood clots After the fluid had been withdrawn from the pericardium, the patient s condition was noticeably improved

Fig 5 is from a further case in which percutaneous catheterization of the pericardium was performed in the way described above A heart catheter had been introduced from the right femoral vein to the main trunk of the pulmonary artery but the catheter recoiled to the right ventricle on the injection of contrast medium into the pulmonary artery The jet of medium through the catheter tip perforated the anterior wall of the right ventricle and a large part of the contrast medium thus found its way into the pericardium After some hours the blood pressure slowly sank and evacuation of the medium from the pericardium was accordingly deemed necessary The position of the mandrin in the pericardial cavity and the contrast medium in the latter is seen in Fig 5a A catheter has been introduced into the pericardium (Fig 5b) and some of the medium and blood having been withdrawn the catheter was left in position for some hours after which it could be removed No further signs of imminent heart tamponade appeared

The pericardium was catheterized in a further two cases in both of which it wa possible to avert imminent cardiac tamponade No complication has so far been observed in connection with this procedure

Conclusion

Several advantages may be attained with catheterization of the pericardium as compared with pericardial puncture with a needle formerly used for aspirating fluid in impending cardiac tamponade A catheter makes it possible to control continuously further hemorrhage or other fluid in the percardium and may save the patient a pericardiotomy Rather effective evacuation of the pericardium may also be attained if during the aspiration the patient is placed in different positions

This catheterization technique may also open up possibilities for an effective local administration of drugs to the pericardium The catheterization may be performed under local anesthesia without any great discomfort to the patient and is technically relatively simple It does, however, as far as can now be seen, suggest the use of roentgen television, under such conditions it is probably safer than blind puncture of the pericardium with a sharp needle

SUMMARY

Preliminary investigations in the dog have indicated that it is possible to introduce catheters percutaneously to the pericardium under roentgen television control This has been utilized in four human subjects in which blood or contrast medium were removed from the pericardial cavity for the relief of imminent cardiac tamponade The technique is simple and seems to offer advantages over conventional puncture of the pericardium

ZUSAMMENFASSUNG

Vorläufige Untersuchungen am Hund haben gezeigt dass es möglich ist einen Katheter subkutan in den Herzbeutel unter Röntgenfernsehkontrolle einzuführen Dieselbe Methode *wurde an vier menschlichen Patienten angewandt um Blut oder Kontrastmittel* aus dem Herzbeutel zu entfernen um eine drohende Herztamponade zu verhüten Die Technik ist einfach und wahrscheinlich mehr erfolgreich als die gewöhnliche Punktion

RÉSUMÉ

Une expérimentation préliminaire sur le chien a montré qu il est possible d introduire par voie percutanée cathéters jusqu au péricarde sous controle radioscopique télévisé Cette technique a été utilisée chez quatre malades pour retirer de la cavité péricardique du sang ou un moyen de contraste faisant craindre une tamponade cardiaque La technique est simple et semble présenter des avantages sur la ponction classique du péricarde

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ANGIOCARDIOGRAPHIC MEASUREMENTS OF THE CARDIAC VENTRICLES IN DOGS

by

ERIK CARLSSON

Angiocardiographic methods for volume measurements of the left ventricle have been described by several authors (ARVIDSSON 1961 CHAPMAN et coll 1958 DODGE et coll 1960) The methods are based on the assumption that the left ventricle is shaped as a regular geometric solid whose volume may be calculated if certain diameters are known These diameters were obtained from biplane angiocardiographic films CHAPMAN and associates (1958) have designed a direct planimetric cineradiographic method for calculation of the left ventricular volume For calculation of the right ventricular volume in dogs REEDY & CHAPMAN (1963) described an indirect planimetric method

A new angiocardiographic method for volume calculation of the right and left ventricles in dogs has been developed The information available in biplane angiocardiographic films as to the volumes of the ventricles was extracted by cutting of styrofoam models patterned on the angiocardiographic films

The method for making models of the cardiac ventricles is based upon that for the whole heart described by PALMIERI (1920) except that only two projections are used

This work was supported by a grant from the St Louis Heart Association Submitted for publication 4 January 1965

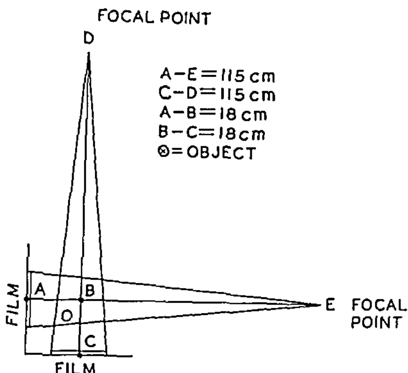


Fig 1 Geometric arrangement of the angiocardiographic examination and the light drawing device

Method

Thirty dogs, each weighing between 12 and 32 kg were used, the average weight being 17 kg Eleven of these dogs were subjected to biplane angiocardiography during nembutal anesthesia (30 mg/kg bodyweight) Cardiac NIH catheters, No 7, with side-holes, were introduced through the femoral artery and the jugular vein, and their tips placed in the right and left ventricles

Angiocardiography was then performed after injection of a Hypaque solution 50 % (1 ml/kg bodyweight) in each of the ventricles A Cordis injector was used for the injection, with a pressure of 4 kg per square centimeter The injection time, 1 CG, and the exposures were recorded on a Sanborn 8 channel recorder In every case, the right ventricle was injected first and, after a varying time interval, the left ventricle In 6 dogs, the left ventricle was injected 3 to 7 min after right ventricular injection and in 5 dogs after an interval of 30 min

Two Schonander cut film changers (25 × 30 cm) were used in orthogonal positions The exposure rate was 6/sec in a 3 sec period for each ventricular injection Anteroposterior and lateral projections were obtained The dogs, on their backs, were suspended in a plastic sheath The focal spot film distance was 115 cm for each projection The central beams of the roentgen tubes



Fig 2 a) Contour tracing of angiocardiographic films of the right ventricle in systole (upper row) and diastole along which styrofoam models were cut Catheters inserted into the right and left ventricles b) Contour tracing of angiocardiographic films of the left ventricle in diastole and systole

were directed toward the center of the film in both projections The distance from the point of intersection between the two central beams to the antero posterior and lateral films was 18 cm

The geometric arrangement is shown in Fig 1

Film pairs exposed in diastole and systole were selected for volume and stroke volume calculations If more than one pair were exposed in systole or diastole the largest diastolic and the smallest systolic volumes were used Film pairs exposed during irregular heart action were not used The cutting of the styrofoam models was adapted to the contour line as shown in Fig 2 Neither the position of the tricuspid nor that of the mitral valve were taken into consideration The contour was drawn along the outer limits of the ventricles and straight through the aortic and the pulmonary ostea below the valve in diastole The relationship between the ventricular volume and the weight of the styrofoam model was then studied

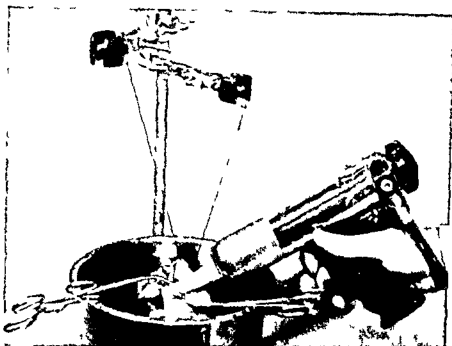


Fig. 3. The heart is suspended in a stand and submerged in water. It is filled with a silicone preparation injected by a device using compressed air.

First, 100 g Silastic RTD silicone rubber and 20 g Silastic RTD thinner were mixed thoroughly and 0.4 g of catalyst 502 was added immediately before use. The silicone preparation was injected into the chambers of the heart with a compressed air injection device (Fig. 3).

Silicone models were made of the ventricular cavities of the dogs subjected to angiocardiography ante mortem, and of 25 additional dogs. To obtain models of the ventricles in various stages of contraction, 15 hearts immediately after removal from the chest were filled with silicone and 17 hearts were filled after 2 days in formalin following the death of the animal. The hearts were removed from the chest with as much extension of the large arteries and veins as possible. The two venae cavae and the pulmonary veins were ligated. To preserve its shape, the heart was then suspended in a stand by means of silk sutures and submerged in water (Fig. 3). The auricular appendages were incised and the silicone preparation injected through the openings. When the silicone preparation appeared in the pulmonary artery and in the aorta, the injection was stopped. The vessels, as well as the incisions in the auricular appendages, were then ligated. Both the left and the right ventricles of each heart were injected to maintain the shape of the chambers. Thirty minutes after the ligation, the silicone was set and the cast could be removed.

The contour of the silicone models was then traced in a device that represent

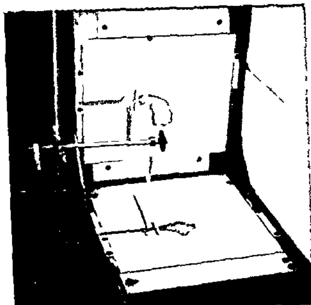


Fig 4 Two pin point sources of light illuminate the silicone model which is mounted in a stand Their position to the silicone model is the same as that of the focal spots of the roentgen tubes to the heart during angiocardiography

ed the geometric conditions during angiocardiography but light was used instead of the roentgen rays (Fig 4) The silicone models were suspended in the device in the same position as were the hearts during angiocardiography Positioning was aided by the ante mortem angiocardiographic films of the same heart When no ante morten films had been obtained the silicone models were fitted to films of a similar sized heart of another dog The ventricular models were then rotated plus 10 and minus 10 from the suspended position around the craniocaudal axis of the ventricles and the contour drawings made in these positions

The contour drawings were used in the same manner as the angiocardiographic films as patterns for cutting styrofoam models of the ventricles An electrically heated wire regulated by a rheostat was used to cut the styrofoam (Fig 5) The cutting arm in the device represented the contour forming roentgen ray during angiocardiography as well as the shadow producing light beams in the drawing device The distance from the point of suspension to the freely movable tip which follows the contour of the ventricle was 115 cm The styrofoam models were cut out of a block that rested upon a platform (Fig 5) The center of the platform was at a point 18 cm from the film planes

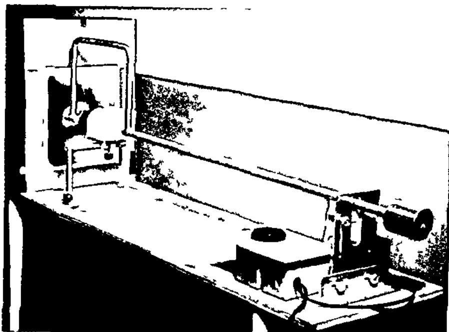


Fig 5 An electrically heated wire cuts the styrofoam block fixed to a platform whose center is located 18 cm from the film plane The cutting arm measuring 115 cm from its point of suspension to the tip follows the contour of the right ventricle on the film The arm represents the light beam of the drawing device as well as the beam of the rcentgen tube during angiocardiography For cutting in the orthogonal plane the platform with the styrofoam block attached is rotated 90 and the film is replaced by one in the other plane

The styrofoam block was rotated 90° around this point from the lateral projection to the anteroposterior projection

The weights of the styrofoam models and of the silicone models were then plotted in a diagram and their relationship analyzed The specific density of the styrofoam (HD 2) was 0 069 to 0 072 and the density of the silicone mass was 1 01 Thirty two right ventricular silicone models and 36 left ventricular models were examined For each silicone model, three styrofoam models were cut

The variation among triplets of styrofoam models constructed from the same silicone model increased as the weight of the silicone model increased Trial and error showed that if for each observed weight $\log_e$ weight was substituted, then the variation among the styrofoam triplets did not depend on the weight of the silicone model A graph of the average $\log_e$ weight of the styrofoam models versus the $\log_e$ weight of the silicone models indicated that a simple linear relationship fitted the data adequately for the right ventricle For the left ventricle a cubic function gave a significantly better fit Approxi

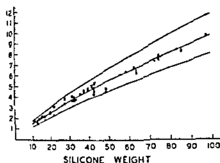


Fig 6 Dots represent observed values of the weight of 96 styrofoam models plotted against weight of 32 silicone models of right ventricle Middle line is the one of best fit its equation being Y = 1 5048 + 0 8195 X where Y = log weight of styrofoam models and X = log weight of silicone models The outer lines represent 95 confidence intervals for a single styrofoam model

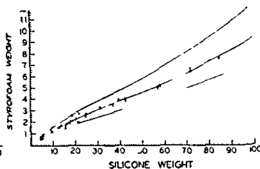


Fig 7 Dots represent observed values of weight of 108 styrofoam models versus weight of 36 silicone models of left ventricle Middle line is the one of best fit its equation being Y = 3 2600 + 2 5164 X − 0 5714 X² + 0 0617 X³ where log weight of styrofoam models and X = log weight of silicone models The outer lines represent 95 confidence intervals for a single styrofoam model Superimposed dots occur

mately 95 per cent confidence limits were obtained for the $\log_e$ weight of a single styrofoam model these limits were transformed back into weights The results are presented graphically for the right and left ventricles in Figs 6 and 7 The following values were obtained

for *the right ventricle* $Y = 1\ 5048 + 0\ 8195\ X$ standard error about the fitted line 0 0724 (30 degrees of freedom) standard deviation among the log weights of the styrofoam triplets 0 0643 (64 degrees of freedom),

for *the left ventricle* $Y = 3\ 2600 + 2\ 5164\ X - 0\ 5714\ X^2 + 0\ 0617\ X^3$ standard error about the fitted line 0 104 (39 degrees of freedom) standard deviation among the $\log_e$ weights of the styrofoam triplets 0 0584 (82 degrees of freedom)

The results of the volume calculations of the right and the left ventricles in 11 dogs are shown in Fig 8 In the six cases in which the left ventricular injection followed the right within a few minutes a markedly larger stroke volume for the left ventricle was measured In the five cases in which the left ventricular injection was delayed for 30 minutes the stroke volumes of the right and the left ventricles were approximately the same

Discussion

The method described for angiographic measurement of the volume of the cardiac ventricles does not require tedious calculation The procedure is simple when the styrofoam cutting device has been adapted to the geometric

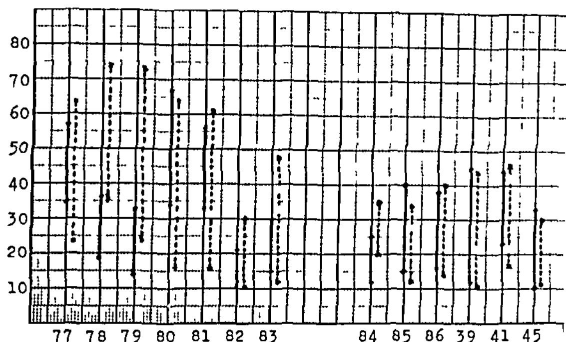


Fig. 8. Ventricular volume in milliliters is indicated along Y axis. Numbers along X axis identify the dogs. Solid line represents right ventricular stroke volume and dotted line left ventricular stroke volume. In the first 6 dogs the right ventricles were injected first, followed immediately by *left* ventricular injection; in the last 5 dogs the left ventricular injection was delayed 30 min after the initial right ventricular injection.

conditions of the angiocardiographic apparatus. It can be used for both the right and left ventricle. The projections are anteroposterior and lateral, the most commonly used projections for anatomic angiocardiographic examinations. The anteroposterior lateral position can be reproduced most precisely on repeated examinations. The styrofoam method represents an innovation in the method of extracting information from the angiocardiographic films. The same principles have been used by PALMIERI (1920) for volume calculation of the whole heart. The possible errors in calculation of the stroke volume that originate in the injection technique and in the physiological response to the contrast medium are the same as those with other angiocardiographic methods of calculating the ventricular volume. The changes in cardiac output after injection of contrast medium described by TRITSINGER (1961), and which we have observed, must be taken into consideration when studies are repeated. The results in our comparisons between right and left ventricular output (Fig. 8) reflect the change in cardiac output following the first injection of contrast medium. Irregular heart rhythm caused by the catheter or by the injection of contrast medium occurred initially in almost every case, as indi

cated by the simultaneous ECG tracing, but normal beats could be found in the subsequent course of the examination

The styrofoam method is not based upon the assumption that the ventricles are shaped as a regular geometric solid Neither the right nor the left ventricle is geometrically regular this is apparent from examination of the silicone models The diagrams describing the relationship between the weights of the styrofoam models and of the silicone models must be determined for the geometric conditions of the angiocardiographic set up and the number of observations be adequate for statistical analysis During angiocardiography the shape of the ventricles may differ somewhat from that of the silicone models The models however, probably approximate as closely as possible the ventricles Results obtained with them should equal the accuracy of those obtained after filling the ventricles with a known amount of contrast medium (DODGE et coll 1960) Wide variations in the state of contraction occur post mortem (MAC WILLIAM 1901), not necessarily representing the shape of the ventricles found in vivo

Whether the systole simulating ventricular models obtained after submerging the hearts in formalin actually represent the systolic shape of the ventricles is difficult to tell On comparison the contour in drawings agrees well with that of the same heart in angiocardiographic films obtained in vivo This comparison applies also to the diastole simulating models which were made from freshly removed hearts

If the position of the heart in the roentgen cone is changed the relationship of the weight of the styrofoam model to that of the silicone model may change the diagrams in Figs 6 and 7 can be applied only to the position in the roentgen cone which was used with the hearts of eleven dogs examined by angiocardiography The models from dogs not examined angiocardiographically were analyzed in this same position The correlation between the styrofoam method and other angiocardiographic methods for volume calculations of the cardiac ventricles will be investigated Correlation to physiologic methods such as the Fick method indicator dilution method and direct flow measuring techniques will also be studied

The application of the styrofoam method to human hearts will be described in a future report

Acknowledgements

The author wishes to express his gratitude to Docent Bjorn Nordenstrom for valuable initial discussion and to Messrs Charles Dunn Robert Feldhaus and William Mockbee of The Edward Mallinckrodt Institute of Radiology for technical assistance The statistical data were calculated by Miss Mary Epl ng of the Computer Center at the University of California San Francisco Medical Center

SUMMARY

A method for volume calculation of the right and left ventricles of the heart in dogs has been developed using biplane angiocardiographic films as patterns for cutting styrofoam models The relationship between the weight of the styrofoam model and the true ventricular volume represented by silicone models of the ventricles has been statistically analyzed

ZUSAMMENFASSUNG

Eine Methode zur Volumenberechnung des rechten und linken Ventrikels von Hunden wurde entwickelt wobei biplanare angiokardiographische Filme als Vorlage fur die Anfertigung von Styroform Modellen verwendet wurden Die Beziehung zwischen dem Gewicht dieser Modelle und dem wirklichen Ventrikelvolumen das mittels Siliconmodellen dargestellt worden war, ist statistisch analysiert worden

RÉSUMÉ

L auteur a mis au point une méthode de calcul du volume des ventricules droit et gauche du coeur du chien Des films d angiocardiographie bidirectionelle ont servi de patron pour découper des modeles en mousse de polystyrène La relation entre le poids du modèle en mousse de polystyrène et le vrai volume ventriculaire représenté par un moulage des ventricules en silicone a été analysée statistiquement

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FROM ROENTGEN DEPARTMENT I (DIRECTOR KJELD ANDERSEN) BISPEBJERG HOSPITAL THE ROENTGEN DEPARTMENT (DIRECTOR H ELTORM), COPENHAGEN COUNTY HOSPITAL GLOSTRUP, AND THE ROENTGEN DEPARTMENT (DIRECTOR PROF GREGERS THOMSEN) AND MEDICAL DEPARTMENT B (DIRECTOR PROF A TYBJAERG HANSEN) OF THE UNIVERSITY HOSPITAL COPENHAGEN DENMARK

ROENTGENOLOGIC CHANGES IN PROTEIN LOSING ENTEROPATHY

by

O CH POCK STEEN

Protein losing enteropathy or Gordon s disease is a rare condition characterized by loss of protein through the intestinal wall

Gastro intestinal loss of protein occurs in numerous lesions of the digestive tract e g coeliac disease regional enteritis, and carcinoma of the stomach it was first described by MOSCHOWITZ (1933) in ulcerative colitis The loss of protein is often greater in protein losing enteropathy however and the cardinal sign is oedema caused by the hypoproteinaemia Concomitant dyspepsia with diarrhoea and steatorrhoea is not infrequent A type occurring during the first months of life seems to have considerable tendency to spontaneous regression (ULSTROM et coll 1956 DOOREN et coll 1961) while the adult type is generally stationary or slowly progressive

It is unknown whether protein losing enteropathy represents a disease sui generis or is a manifestation of different disorders the latter conception being more probable Oedema of the intestinal mucosa is evident micro

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Table

Roentgenologic signs in 9 patients with protein losing enteropathy in a series of 19 examinations of the small intestine

Patient number	Transit time in hours		Enlarged jejunum	Enlarged ileum	Biconvex valvulae conniventes	Radiate fragmentation
	Ileum	Caecum				
1	3	4	(+)	—	(+)	+
	3	4	(+)	+	+	+
	3	4	+	+	(+)	(+)
	2	4	+	+	+	+
2	2	4	+	+	+	+
	2	3	+	+	(+)	+
	2	4	+	+	+	+
3	3	5	+	+	+	(+)
4	2	3	+	(+)	(+)	
	1	2	+	(+)	+	—
	1	2	+	–	+	—
5	2	4	+	+	+	
6	1/2	1	+		+	+
7	3	7	+		–	
	3	6	+			(+)
	3	4	—	–	+	(+)
8	1	3	–	(+)	+	(+)
	1	4	–	–	+	(+)
9	1	[illegible]		+		–

scopically in all cases and often enlarged lymph vessels and increased vascularization as well. Deposits of lipofuscin granula in the muscularis mucosae and infiltration with plasma cells and lymphocytes in the submucosa often occur; eosinophilia is sometimes present.

Roentgen appearances. The roentgenologic changes in the small intestine have been mentioned only occasionally in the literature, and en passant in clinical publications where they have been described as enteritis or 'sprue-like'. Although some cases have been interpreted as normal, most authors mention prominent valvulae conniventes. Among 20 cases of so-called 'jejunitis

Table (*cont.*)

Segmentation	Flocculation	Moulage	Effusion into the lumen	Ascites
—	—	—	—	(+)
—	—	—	—	—
—	—	+	—	—
—	—	—	—	(+)
—	—	—	—	+
—	—	—	—	(+)
—	—	—	—	+
(—)	—	—	—	+
—	—	—	—	—
—	—	—	—	—
—	—	—	—	+
—	—	—	—	—
—	—	—	—	—
—	—	—	—	(+)
—	—	—	—	(+)
—	+	—	+	+
(—)	—	—	—	(+)
( )	—	—	—	(+)
+	—	+	+	+

CATTAN et coll (1962) described one case with a significant loss of protein This case was characterized by prominent valvulae conniventes and was probably one of protein losing enteropathy The most thorough description of the roentgenologic signs in protein losing disorders of the digestive tract has been given by MARSHAK et coll (1961) These authors described two cases of Gordon s disease among 7 cases of gastro enteropathies involving protein loss Three cases of the latter were however secondary to regional enteritis In the two cases of Gordon s disease the authors noticed very prominent valvulae conniventes in both the jejunum and the ileum and a more or less marked effusion into the lumen However they were inclined to regard these signs as unspecific

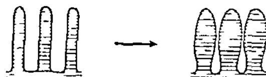


Fig. 1. Schematic drawing of valvulae conniventes without and with oedema. The barium-filled space between two adjacent valvulae conniventes will appear biconcave in the latter condition.

Present material. We have had the opportunity during the last two years to study a series of findings in the small intestine in 10 cases of protein losing enteropathy comprising 5 males and 5 females, aged between 18 and 67 years (see Table). One of these had had intermittent dyspepsia, steatorrhoea and oedema since infancy, whereas the others developed no signs or symptoms until they were adults. The protein metabolism of 8 of the cases has been described by SCHWARTZ (1961) and JARNUM (1963).

All cases were subjected to several roentgenologic examinations of the stomach, small intestine, and colon. Ordinary barium sulphate suspensions were employed. No specific features were noticed in the roentgenologic examination of the stomach and the colon, whereas in all cases but one a striking similarity was evident between the various series of the small intestine of the same case.



Fig. 2. Roentgenologic typical biconcave mucosal pattern in a male aged 41 with intermittent diarrhoea, steatorrhoea and oedema of the legs at one hour after a barium meal. Abundant filling of the small intestine; the coils are slightly distended and lie in smooth curves.

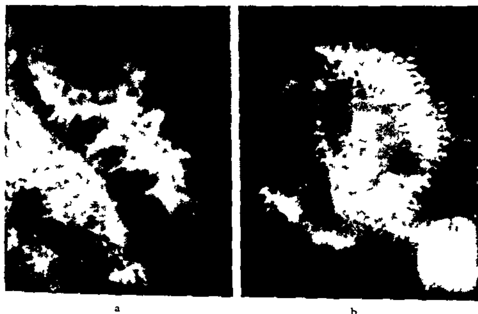


Fig 3 a) Roentgenologic appearances almost identical with those in fig 2 in a female aged 36 with oedema of the legs and intermittent diarrhoea for 20 years Laparotomy performed 5 years previously revealed chyloascites a thickened intestinal wall with enlarged subserosal lymph vessels and lipofuscinosis of the muscularis mucosae b) Protein losing enteropathy in a male aged 50 with oedema of the legs and ascites for 35 years Typical biconcave pattern present but no enlarged jejunal coil

performed at different times as well as between the series of the small intestine in different cases As these signs and symptoms conform with the gross pathologic features of protein losing enteropathy they may perhaps be regarded as characteristic

The middle part of the valvulae conniventes in protein losing enteropathy is prominent and thickened by oedema the valvulae thus become biconvex (schematically drawn in Fig 1) The roentgenologic mucosal pattern caused by the barium filling of the spaces in between must consequently be biconcave This pattern was noticed as a very prominent feature (Fig 2) in all but one of the cases These changes begin at the duodeno jejunal flexure and are often present both in the jejunum and the ileum A strikingly abundant barium filling of the entire small intestine has also usually been observed and by one hour the intestinal coils seem to fill the whole abdomen The jejunum is generally enlarged and the coils lie in smooth curves without sharp bends as if slightly distended These signs are probably also caused by oedema of the intestinal wall As the intestine is not rigid peristalsis will be present although



Fig 4 No biconcave mucosal pattern is evident in a male aged 41 with chronic pyelonephritis and severe hypoproteinaemia and oedema

less marked The small intestine in another case is depicted in Fig 3a, the *similarity with the small intestine in Fig 2 is obvious The contours of the* valvulae conniventes were sometimes blurred, probably indicating marked oedema, ascites was present in many cases Two of the cases had no enlarged coils of intestine but had the same characteristic biconcave mucosal pattern (Fig 3b)

Most of the cases have been followed up for many years Their state of hypoproteinaemia and oedema may have varied from time to time but it has not been possible to find a correlation between the severity of the hypo proteinaemia (reflected by the oedema) and the roentgenologic changes of the small intestine

Discussion

The conformity of the roentgenologic appearances of the small intestine in cases of protein losing enteropathy contrasts with many other disorders



ɔ Protein losing enteropathy in a m le aged 5ɔ with oedema of the legs and ascites The t nal co ls are demonstrated p ior to (a) and dur ng a fat f ee d et (b) The markedly biconcave ·rn of (a) has disappeared in (b) (By courtesy of J RNUM & JENSEN)

he small intestine and generally makes the diagnosis easy The diagnosis protein losing enteropathy was suggested in the last three cases studied hout any knowledge of the clinical findings in the patients concerned
The changes described are probably caused by local oedema of the valvulae niventes and not by general oedema These features are absent in hypo oteinaemia with oedema caused by other disorders Fig 4 depicts a small estine of nearly normal pattern in a case of chronic pyelonephritis with rked hypoproteinaemia (albumin 2 7 g/100 ml) In other conditions such nephrosis biliary cirrhosis and peritoneal carcinosis with oedema and/ ascites the previously mentioned symptoms and signs of protein losing teropathy have not been noticed These roentgenologic changes are thus t caused by the hypoproteinaemia or the ascites but seem related to a local ocess in the intestinal wall In this connection it is of interest to mention at JEFFRIES et coll (1964) have found that a fat free diet decreases the eatorrhoea and causes an increase in plasma proteins and a resolution of e oedema JARNUM & JENSEN (1964) were recently able to confirm these bservations The clinical remission was followed by a significant regression f the biconcave mucosal pattern (Fig 6) and peroral biopsy of the small



Fig. 6. From the same case as illustrated in fig. [illegible]. Peroral intestinal biopsy prior to (a) and during treatment with a fat free diet (b). The mucosal oedema in the former has clearly diminished in the latter. (By courtesy of JARNUM & JENSEN.)

intestine before and during a fat free diet confirmed the decrease in the mucosal oedema (Fig. 6).

The similarity in the roentgenologic changes in the investigated cases of protein losing enteropathy suggests an entity in nine (see Table). As previously mentioned, the small intestine in one of the cases had none of the characteristic features including the biconcave pattern. These were replaced by an irregular mucosal pattern in the jejunum, loss of the transverse pattern of the dilated coils of ileum, and a more marked exudation into the lumen; the hypoproteinaemia was less marked than in the other cases but otherwise the clinical picture was identical. The present state of knowledge makes it difficult to decide whether this case represents an earlier stage of protein losing enteropathy or an entirely different condition.

Conclusion

Protein losing enteropathy seems roentgenologically to be characterized by conspicuous appearances, with broad biconvex valvulae conniventes and a biconcave mucosal pattern especially of the jejunum. The small intestine is generally slightly dilated and seems to fill the entire abdomen. Peristalsis is less marked. The roentgenologic signs are probably caused by oedema of the intestinal wall, especially of the valvulae conniventes, where the oedema is more marked than in the corresponding grade of hypoproteinaemia.

SUMMARY

The characteristic roentgenologic gastro-intestinal features in 10 cases of protein losing enteropathy are described It is suggested that the changes are probably caused by oedema of the wall of the bowel particularly of the valvulae conniventes

ZUSAMMENFASSUNG

Die Rontgenerscheinungen am Magen Darmkanal von 10 Fallen von Protein Verlust werden besprochen Es erscheint dass solche Veranderungen durch Ödem der Valvulae conniventes verursacht werden

RÉSUME

Description des signes radiologiques gastro-intestinaux caractéristiques de 10 cas d entéropathie avec perte de protéine L auteur pense que ces aspects sont probablement causés par l œdème de la paroi intestinale en particulier au niveau des valvules conniventes

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IODINATED OIL EMULSION FOR LYMPHOGRAPHY

by

S. JOHANSSON, N.-H. STERNBY, G. THEANDER and L. WEHLIN

The first contrast medium successfully used for lymphography in man seems to have been Thorotrast, a colloidal suspension of thorium dioxide. In 1944, SERVELLE reported 2 cases of lymphangiectasis that had been studied roentgenographically after percutaneous injection of this suspension into dilated lymph vessels. Thorotrast had previously been employed for various other roentgenographic procedures. It had, for example, been given intravenously for the demonstration of the liver and spleen, the colloid particles accumulating and persisting in the reticuloendothelial system (KADRNKA 1931, and others). Thorium proved, however, to be carcinogenic owing to its radioactivity and extremely slow elimination and to be liable to produce liver cirrhosis (BUDIN & GERSHON COHEN 1956, THOMAS 1962). Thorotrast is therefore no longer acceptable as a diagnostic agent in man.

A further colloidal metal compound, stannic oxide, has also been employed for lymphography as well as for hepatosplenography, but as far as is known only in animals (FISCHER 1957, FISCHER & ZIMMERMAN 1959). This preparation is not radioactive but resembles Thorotrast in being retained in the reticulo-

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endothelial system and not metabolized Its use as a contrast medium may thus constitute a serious potential hazard

A different group of contrast media came into common use for lymphography with the adoption of a suitable technique for cannulation of peripheral lymph vessels in man (KINMONTH 1952) This group comprises various water soluble iodine compounds synthesized for urography and angiography (e g diodone sodium acetrizoate and sodium diatrizoate) or for cholegraphy (iodipamic acid) and known to have low toxicity Such media have been successfully employed for roentgen examination of the main superficial lymph vessels and regional lymph nodes of the limbs (COLETTE 1958, KAINDL et coll 1960 WELIN 1960 JACOBSSON & JOHANSSON 1962 and others) Owing to their rapid diffusion from the lymph vessels and nodal sinuses a satisfactory demonstration of the lymph system of the trunk cannot be achieved by means of these media

A third group of contrast media consisting of various iodinated vegetable oils (e g Lipiodol and Ethiodol), have been widely used during the last few years for lymphography in man (BRUUN & ENGESET 1956 SHANBROM & ZHEUTLIN 1959 and others) These do not diffuse through the wall of the lymphatics and therefore permit the entire chain of lymph channels and nodes ascending from the region of injection to be demonstrated For example a dose of 10 to 20 ml injected into a lymph vessel of the foot is usually sufficient for an examination of the regional as well as of the corresponding pelvic retroperitoneal and thoracic lymph vessels and nodes The high viscosity of the oil and the small calibre of the lymph vessels make it necessary to keep the rate of injection low (usually about 10 ml/hr)

Both the oily and the aqueous contrast media are capable of being metabolized and removed from the body They differ however, considerably in the rate of elimination the former being retained longer in the lymph system particularly in the nodes Lymph nodes demonstrated with iodinated oil are usually still visible in roentgenograms two to three months after the injection and residual oil has occasionally been observed in the nodes after more than two years (JOHANSSON et coll 1965) This prolonged retention has the obvious advantage that the lymph nodes may be reexamined roentgenographically for a considerable period without repeated injection On the other hand the retention of oil in the nodes has been found to produce a foreign body reaction and may cause permanent damage

A further important difference between the oily and aqueous lymphographic media is that the former may form emboli in the blood vessels Pulmonary changes suggesting lung embolism have been demonstrated roentgenographically after lymphography with oil (Fig 1) A recent review of complications

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IODINATED OIL EMULSION FOR LYMPHOGRAPHY

by

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The first contrast medium successfully used for lymphography in man seems to have been Thorotrast, a *colloidal suspension of thorium dioxide* In 1944, SERVELLE reported 2 cases of lymphangiectasis that had been studied roentgenographically after percutaneous injection of this suspension into dilated lymph vessels Thorotrast had previously been employed for various other roentgenographic procedures It had, for example, been given intravenously for the demonstration of the liver and spleen, the colloid particles accumulating and persisting in the reticuloendothelial system (KADRNKA 1931, and others) Thorium proved, however, to be carcinogenic owing to its radioactivity and extremely slow elimination and to be liable to produce liver cirrhosis (BUDIN & GERSHON COHEN 1956, THOMAS 1962) Thorotrast is therefore no longer acceptable as a diagnostic agent in man

A further colloidal metal compound, stannic oxide, has also been employed for lymphography as well as for hepatosplenography but as far as is known only in animals (FISCHER 1957 FISCHER & ZIMMERMAN 1959) This preparation is not radioactive but resembles Thorotrast in being retained in the reticulo

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have been shown to accumulate in the reticuloendothelial system but have proved unstable and hazardous and therefore been discarded (KEITH & BRIGGS 1930 OSELLADORE & LENARDUZZI 1937, DEGKWITZ 1938 OLSSON 1941 GROSSMANN & COORAY 1949/50 BERGER 1956 GOLDBERG & FEINBERG 1963)

A new Ethiodol emulsion recently described by TEPLICK et coll (1964), may seem promising since it was claimed to have an average particle size of about 0 3 μ and to have been stable for periods up to 6 months It had been successfully employed in various experiments including lymphography in dogs but its use in man had been limited to cystography and gastrointestinal examinations

Two of the present authors (THEANDER & WEHLIN 1962) studied an emulsion of iodinated oil with a maximum particle diameter of about 2 μ in an investigation of selective nephroangiography with various contrast media in dogs This emulsion had also been stable for several months in vitro but it was later shown that in the presence of blood one of its components tended to precipitate, and rapidly formed flakes of considerable size A modified emulsion without this component has since been prepared The present communication is concerned with an experimental study of the latter preparation and with some observations made on lymphography with this contrast medium in man

Preparation of the emulsion The emulsion was prepared by a two step procedure developed by the pharmaceutical research department of AB Leo Halsingborg Sweden The first step was to produce a highly stable base preparation from which as the second step the final emulsion could be easily obtained immediately before the injection

The base preparation consists of an emulsion of the iodinated ethyl ester of poppy seed oil (Lipiodol F) in glycerol with soya bean lecithin as an emulsifying agent It contains 0 25 g iodine/ml and is miscible with blood as well as with water but since its viscosity is much higher than that of Lipiodol F or Lipiodol Ultrafluid (about 10 000 130 and 46 cp respectively) it was not considered suitable for intralymphatic injection The final emulsion was obtained by diluting the base preparation with a 5 5 % solution of glucose in water Four such mixtures with different proportions of glucose were used in the investigation These had an iodine content of 0 18 0 16 0 13, and 0 10 g per ml and the corresponding viscosities were 60 28 11 and 6 cp All the viscosity values mentioned refer to measurements made at room temperature with a Brookfield synchro lectric viscometer The relevance of these values is uncertain since it is possible that the viscosity studied is not a true measure of the relative resistance offered to the flow of different liquids through a thin vessel



Fig 1 Part of the left lung before (a) and one day after (b) lymphography with Lipiodol Ultrafluid (10 ml per leg) Stippling caused by oil embolism is seen in (b)

of lymphography (JOHANSSON et coll 1965) left no doubt that lymphography with oil is often, if not invariably, accompanied by oil embolism It is apparent *from this review that, although such embolism usually produces slight or no* clinical signs, it has occasionally been responsible for severe and even fatal reactions to lymphography

It is evident from the experience with current lymphographic media that these are far from ideal It seems fair to conclude that *lymphography will* be *much more informative if performed with an oily than with any known* water soluble contrast medium, but lymphography with oil doubtless in volves risks of embolism that should not be ignored A lymphographic medium without this disadvantage, but similar to oil in being non diffusible but *capable of being metabolized, is therefore highly desirable*

It has long been realized that a suspension or emulsion of an iodinated oil with particles small enough to pass through the capillaries might provide a contrast medium suitable for various kinds of roentgen examinations Many such preparations have been produced and after *intravascular injection*

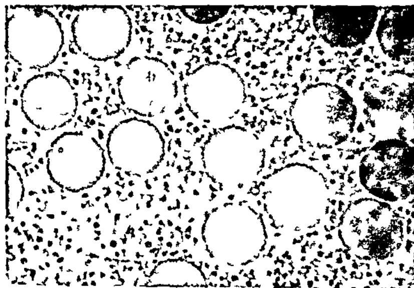


Fig 2 Photomicrogram of a final emulsion mixed 2 5 with human heparin blood × 2 500 The size of the oil particles is small in comparison with the size of the erythrocytes

of a tween lecithin broth and incubated at 37 C One and three days later samples were taken from these broths and inoculated on blood agar plates with peptone which were studied for growth after incubation at 37 C

The observations made on comparison of these experiments are summarized in Table I which shows a definite bactericidal effect of the base preparation on all the species studied All the experiments mentioned were repeated with similar results In a corresponding series of control experiments the tween lecithin broth invariably prevented the bactericidal action of the base preparation

The final emulsion was studied in vitro by microscopic examination of each of the four above mentioned mixtures of base preparation with *glucose* Samples were taken from fresh mixtures as well as from mixtures stored at 4 to 8 C for up to 2 months The size of the particles in all of these samples was found to be roughly the same as in the base preparation The mixtures mentioned were also studied for their compatibility with blood by adding various proportions of human blood pretreated with heparin to prevent coagulation The amount of blood added ranged from 2 5 ml to 20 ml *per millilitre* of emulsion These mixtures of final emulsion with blood were examined microscopically at various intervals over a total period of more than 3 days They proved to maintain a Brownian particle movement except that many erythrocytes had attracted oil particles which still adhered to the red cells With this exception no aggregation of oil particles or erythrocytes was found to occur and no formation of a precipitate could be demonstrated A photomicrogram of a fresh 2 5 mixture of final emulsion and blood is shown in Fig 2 It should be added that on comparison of droplets of blood with and without admixture of emulsion the former were found to have a more even distribution of red cells and showed definitely less rouleaux formation

Table 1

Observed effect of base preparation on various kinds of bacteria figures referring to different suspensions shown to have become sterile after incubation with base preparation at 4° C for the various times given

	Minimum number of bacteria killed per millilitre of base preparation in		
	1 1/2 hour	24 hours	48 hours
E coli	240	1 700	170 000
P vulgaris	8	200 000	
Ps pyocyaneus	1 600	12 000	160 000
B subtilis	1 000		
Staph aureus	100	110 000	

In vitro observations

The base preparation was studied microscopically, chemically and bacteriologically Microscopy disclosed that all visible oil particles were in brisk Brownian movement The particles were of somewhat different sizes but the diameter was never found to exceed 1 μ, and the vast majority of particles were smaller than 0 5 μ in diameter To check the stability of the emulsion, comparison was made between fresh samples, those stored at 4° C to 8° C for periods up to two years, and those transported 2 000 km in phials by train, these were not found to differ appreciably in maximum or average size of particles

Chemical analysis of fresh and 2 year old samples of the base preparation revealed no free iodide

The bacteriologic investigation indicated that the base preparation was autosterile and was therefore extended to include a study of a base preparation inoculated with various bacteria (I Juhlin, the Department of Bacteriology) The following experiments were performed separately with *E coli*, *P vulgaris*, *Ps pyocyaneus*, *B subtilis*, and *Staph aureus*

Four different suspensions of bacteria were obtained by successively diluting a broth culture 1 10 1 10^4 1 10^6 and 1 10^8 with normal saline Two series of samples (0 10 and 0 05 ml) were taken simultaneously from all these suspensions The first mentioned samples were spread over blood agar plates with peptone and incubated for 18 hours at 37 C The colonies then found on the respective plates were counted and the number of bacteria that had been present per millilitre of suspension was calculated Each of the other samples of suspension was mixed 0 02 1 with base preparation and kept at 4 C for periods ranging from 1 1/2 hour to 14 days Of each mixture 0 1 ml was then transferred to 5 ml

CONTRAST MEDIUM (C M)	DOSE OF C M/Kg BW IN ml	IN g OF IODINE	INTERVAL BETWEEN INJ OF C M AND DEATH IN HOURS 0	< 12	40	65	90
LIP IODOL F	05 07	026 - 036			□ □ □(++)	□(+)	□(+)
	1	052	□	□			
	2	104	□				
EMUL SION	1	016			□ □ □ □ □ □ □	□ □ □	
	3	048			□ □ □ □	□	□ □ □ □ □ □ □
NO CONTRAST MEDIUM			□ □ □ □ □ □				

Fig 3 D stribution of slight (+) moderate (++) and marked (+++) pulmonary lesions in 30 rabb ts studied at various ntervals after intravenous injection of a vary ng dose of Lipiodol F or emuls on nd in 6 controls Each square represents one animal

widespread inflammatory lesions particularly in the lungs These lesions were similar in all of the twelve animals mentioned and probably due to the para sites to facilitate interpretation of the histologic findings these animals were therefore excluded

Twenty two of the remaining 36 rabbits received various doses of the final emulsion containing 0 16 g iodine/ml Various doses of Lipiodol F were given for comparison in another series comprising 8 animals Either preparation was injected intravenously at an approximate rate of 250 ml/hr Three of the animals given Lipiodol F died during (2 cases) or within 12 hours of (1 case) the injection The other 27 animals were killed by air embolism at various intervals after the injection of contrast medium A further series of 6 animals received no contrast medium these were also killed by air embolism and served as controls The number of animals the dose of the contrast medium, and the interval between the injection of the medium and death in the various groups studied are given in Fig 3

All the rabbits were examined post mortem Macroscopically, the lungs sometimes had irregular hemorrhagic areas or whitish nodules but all the other organs appeared normal The heart lungs liver spleen kidneys and brain were examined histologically with haematoxylin eosin Sudan IV and occasionally with van Gieson and osmium stain The histologic findings are summarized below

Intravascular fat was observed in all of the 8 animals that had received Lipiodol F A large amount of such fat was present in the lungs and a small

Table 2

Observed toxicity of fresh final emulsion in NMRI mice expressed as LD_{50}/kg bodyweight and related to age of base preparation and to content of iodine and rate of injection of final emulsion — Confidence limits are given within brackets

Base preparation	Iodine content of final emulsion g/ml	Rate of injection ml/hour	LD_{50}/kg bodyweight	
			ml emulsion	g iodine
Fresh	0.16	20	16.5 (13.3—20.5)	2.64 (2.13—3.28)
2 year old	0.16	20	14.5 (11.4—17.8)	2.32 (1.82—2.85)
Fresh	0.16	250	6.9 (6.3—7.6)	1.10 (1.01—1.22)
Fresh	0.10	250	16.5 (14.1—19.5)	1.65 (1.41—1.95)

Animal experiments

The tolerance to intravascular injection of the emulsion was studied in mice and rabbits. These experiments were performed with fresh final emulsion, i.e. the base preparation and the glucose solution were mixed immediately before the injection.

The toxicity of the emulsion was determined in NMRI mice that received various doses of final emulsion prepared from a fresh or from a 2 year old base. The emulsion employed contained 0.16 or 0.10 g iodine/ml and was injected intravenously at an approximate rate of 20 or 250 ml/hr. The proportion of animals surviving the injection less than 7 days was noted and the LD_{50} was calculated separately for each of the preparations and rates of injection used. The LD_{50} values together with their confidence limits are given in Table 2, which indicates that the LD_{50} of the final emulsion given intravenously at an approximate rate of 20 ml/hr contained about 2.6 g iodine/kg bodyweight. The toxicity was found to increase with the concentration of the emulsion and with the rate of injection but did not differ appreciably with the age of the base from which the emulsion had been obtained.

The tolerance to the final emulsion was further studied in rabbits by histologic examination of specimens obtained from animals that had received emulsion or Lipiodol F, as well as from controls. These experiments were performed in altogether 18 apparently healthy animals. Twelve animals that had been obtained from a different source than the others, and had received various doses of contrast medium (10 cases) or served as controls (2 cases), were however later found to harbour parasites in various organs and to have



Fig. 3. Lymph nodes demonstrated with emulsion at one day (a) and four weeks (b) after injection of the contrast medium

Lesions in other organs were present in 3 animals all of which had received Lipiodol F. These were confined to the brain and consisted of minor hemorrhages which in one case proved to encircle vessels filled with fat.

Lymphography in man

Fresh final emulsion was used for lymphography in 31 cases admitted to the roentgendiagnostic department because of proved or suspected lymphedema (12 cases), leucemia (1 case), systemic lymph node disease (12 cases), or metastases from a carcinoma (5 cases) or sarcoma (1 case). The emulsion was slowly injected into a lymph vessel of the foot. In the first five cases studied the injection was given manually and in the following 26 cases with an injection apparatus constructed by CLEMENTZ & OLIN (1961). Of these 26 cases the



Fig 1 Lymphography with 9 ml Lipiodol Ultrafluid (right side) and with 20 ml emulsion containing 0 16 g iodine per ml (left side)

amount in most of, if not all, the other organs examined No intravascular fat could be demonstrated in any organ in the other animals

Pulmonary lesions were present in all animals that had survived an injection of Lipiodol F for 12 hours or more, and in several of the others, including some of the controls These lesions were of the same kind in all the groups of animals but differed considerably in number and severity from one animal to another and ranged from small foci of condensed parenchyma with clusters of leucocytes, lymphocytes and macrophages to extensive and partly hemorrhagic areas with dense collections of such cells and occasionally with necrosis Pulmonary edema and bronchi filled with leucocytes were also observed in some cases

The pulmonary lesions were classed as slight, moderate, or marked according to their number and severity The distribution of these classes in the various groups of animals studied is given in Fig 3 which shows that the pulmonary lesions were more common and more marked in the animals that had received Lipiodol F than in those given emulsion It is also clear that in these respects the emulsion series did not differ appreciably from the controls

Table 3

Observed incidence of rupture of lymph vessels related to rate of injection of contrast medium in 31 cases of lymphography with emulsion

	Manual injection	Injection at constant rate of			Total
		30 ml/hour	20 ml/hour	12 ml hour or slower	
Number of cases studied	5	7	14	5	31
Number of cases with observed rupture	2	3	3	1	9

(14 cases) The total dose of emulsion expressed as the amount of iodine per kg bodyweight was invariably less than 0 2 g and generally less than 0 15 g

Roentgenograms of the legs pelvis and abdomen were obtained during and 24 hours after the injection of contrast medium All the patients were questioned whether they had experienced any discomfort following injection of the emulsion, in 24 cases chest films were taken before as well as immediately and about 24 hours after injection of the emulsion A few of the patients were seen again several weeks or months later and were then further examined by additional radiography of the lymph nodes

The iodine content of the emulsion employed always proved sufficient to demonstrate lymph vessels as well as regional pelvic and retroperitoneal lymph nodes The propagation of the emulsion within the lymph system was not found to differ appreciably in rate or extent from that of Lipiodol Ultrafluid but the lymph nodes demonstrated with emulsion tended to be somewhat less dense than we usually have seen at lymphography with Lipiodol Ultrafluid An example of lymphography performed on one side with emulsion and contralaterally with Lipiodol Ultrafluid is presented in Fig 4

The time the emulsion was retained in the lymph nodes seemed to vary widely In one case for example nodes demonstrated with emulsion were still visible roentgenographically as late as six months after the injection whereas in another case nearly all the emulsion had disappeared from the lymph nodes within four weeks (see Fig 5)

No diffusion of the emulsion was seen but in 9 cases emulsion was found to escape from the lymph system because of rupture of subcutaneous lymph vessels of the legs In one of these cases illustrated in Fig 6, the extravasation was considerable and was followed by marked inflammatory edema and reddening of the leg and thigh The patient recovered from the complication within a week Repeat roentgen examinations revealed a gradual disappearance



Fig 6 Rupture of lymph vessels and extravasation of contrast medium in a leg examined with emulsion during (a) and at one day (b) and 23 days (c) after the injection

rate of injection was 12 ml/hr or lower in five, 20 ml/hr in fourteen, and 30 ml/hr in seven cases

The examination was performed unilaterally in 5 cases and bilaterally in 26, but in three of the latter the emulsion was injected only on one side while the other side was examined simultaneously with Lipiodol Ultrafluid for comparison The dose of emulsion given per leg ranged from 10 to 40 ml and the iodine content per ml was 0 13 g (4 cases), 0 16 g (13 cases), or 0 18 g

uloendothelial system The liver and spleen in various preliminary animal experiments have been roentgenographically demonstrated after intravenous injection of large doses of the emulsion Further investigations are in progress to find out whether an emulsion dose sufficient to provide diagnostic hepatosplenography may be given with safety

Previous animal experiments have shown that the phlebographic phase of nephroangiography can be improved by replacement of the conventional diffusible angiographic media by a corpuscular contrast medium (THEANDER & WEHLIN 1962) It was hoped that the emulsion studied in the present investigation would be useful for this purpose but examination of the kidneys after selective nephroangiography with the emulsion in dogs revealed injuries for which at present no satisfactory explanation can be offered The emulsion studied cannot therefore be recommended for intraarterial injection despite the low toxicity when given intravenously

SUMMARY

An emulsion of the iodinated ethyl ester of poppy seed oil was studied in vitro and in animal experiments and employed for clinical lymphography in 31 cases It appeared more suitable for lymphography than non emulsified iodinated oil

ZUSAMMENFASSUNG

Eine Emulsion von dem jodierten Ester des Mohnsamen Öls wurde in vitro und in Tierexperimenten geprüft und für klinische Lymphographie in 31 Fällen verwendet Die Emulsion schien für Lymohographie besser geeignet zu sein als nicht emulgiertes Jodol

RÉSUMÉ

Une émulsion de l ester éthylique iodé de l huile d oeillette a été étudiée in vitro et sur des animaux et utilisée cliniquement en lymphographie dans 31 cas Elle paraît convenir mieux à la lymphographie que l huile iodée non émulsionnée

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of interstitial contrast medium from the limb but minor residues were still visible 3 weeks after the injection In the other 8 cases mentioned, only insignificant extravasation was observed but in two of them slight lymphangitis ensued and persisted for 2 to 3 days It should be added that in one of the cases studied simultaneously with Lipiodol Ultrafluid and with emulsion, ruptures were seen in the limb examined with the former preparation but not in the other although the dose of the emulsion given in this case was even more than twice the dose of Lipiodol Ultrafluid

The incidence of rupture evident at lymphography with the emulsion was not found to vary with the amount or viscosity of the preparation employed It may have increased somewhat with the rate of injection but the differences noted in the small material studied were insignificant (see Table 3)

Other complications encountered in the present material were local infection at the site of the dermal incision in one case and moderate elevation of temperature, lasting from one to three days, in 16 cases No clinical or roentgenographic signs of oil embolism were observed in the material

Discussion

Observations in the present investigation indicate that the studied emulsion of iodinated oil has many desirable properties as a corpuscular angiographic medium Judging from the studies in vitro, the particles are of suitable size and the stability of the emulsion appears satisfactory within a wide safety margin The autosterility and bactericidal effect of the base preparation also imply considerable practical advantages

The animal experiments produced further evidence that the emulsion is better tolerated in the circulation than non emulsified oil and also indicate that the intravenously injected emulsion passed through the capillaries without causing infarction

The results obtained in preliminary trials in human subjects agree with the findings in animal experiments and suggest that lymphography with the emulsion and with Lipiodol Ultrafluid will afford roughly the same information It is possible, however, that the emulsion will produce less density of the lymph nodes, this may be an advantage since it would appear that nodes demonstrated with oil have sometimes been too dense to allow satisfactory evaluation of their structure

In summary, the emulsion appears more suitable than non emulsified iodinated oil for lymphography

It may be added that in animal experiments the emulsion, as expected, accumulated not only in the lymph nodes but also in other parts of the retic

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